

Water Resources Center Annual Technical Report FY 2015

Introduction

June 2016

Delaware Water Resources Center

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A Watershed Year

The past year (2015-2016) has been a watershed for water resources for the Delaware Water Resources Center and the Diamond State. The DWRC celebrated the Golden Anniversary of our founding at the University of Delaware in 1965, just a year after Lyndon Baines Johnson worked with Congress to sign the Water Resources Research Act that formed water resources institutes at the 54 land grant universities in the United States. DWRC faculty, scientists and students have won national and regional awards, been elected as president of the American Water Resources Association (AWRA), and invited to the White House Water Summit. What will the next decade bring for the DWRC, diamonds anyone?

Dr. Kauffman Appointed as Third Director of the DWRC

In January 2015, Dr. Gerald Kauffman was appointed the third Director of the Delaware Water Resources Center since the center was founded in 1965. Dr. Kauffman succeeds Dr. Tom Sims, Deputy Dean of the University of Delaware's College of Agriculture and Natural Resources who served as the second Director of the DWRC for a decade and a half since 2000 and made a real and substantial difference in the careers and lives of many students, faculty, and scientists who conducted research in water science and policy here at the University of Delaware. The first Director of the DWRC was Dr. Robert Varrin, UD professor of civil and environmental engineering.

DWRC 50th Anniversary

On Friday April 17, 2015, over 50 faculty, staff, and students celebrated the 50th anniversary of the Delaware Water Resources Center's founding at the University of Delaware at its annual meeting and research poster session at the Trabant University Center in Newark, Delaware. Founded in 1965, one year after Lyndon Baines Johnson signed the Water Resources Research Act on July 17, 1964, the DWRC is one of the 54 National Institutes for Water Resources (NIWR) funded by the U.S. Department of Interior and U.S. Geological Survey at land grant universities in the 50 states, District of Columbia, and the three island territories of the Virgin Islands, Puerto Rico and Guam.

The DWRC at UD is part of a land grant-based water research network that stretches from the Atlantic to the South Pacific and includes schools such as California (Berkeley), Georgia Tech, Illinois, Wisconsin, Florida, Ohio State and the University of Guam. The DWRC belongs to the Mid-Atlantic NIWR region with water resources colleagues at Cornell, Penn State, Rutgers, Maryland, Virginia Tech and West Virginia. The DWRC is supported by appropriations from the United States Geological Survey (USGS), the National Park Service, the Environmental Protection Agency (EPA), the National Oceanic and Atmospheric Administration (NOAA), state and local government and foundation sources. DWRC Program Coordinator Maria Pautler in the College of Agriculture and Natural Resources assists Dr. Kauffman in the daily operations of the center and coordinates the undergraduate/graduate student water resources research program.

Third Annual Delaware River Forum

The DWRC co-hosted the 3rd Annual Delaware River Watershed Forum at the University of Delaware on October 5-6, 2015 following the first two symposia at the Academy of Natural Sciences at Drexel University in 2013 and in Bethlehem near Lehigh University in 2014. Over 300 participants from throughout the Delaware River Watershed in Delaware, New Jersey, New York, and Pennsylvania learned about a range of protection and restoration efforts underway, contributed insights to the development of a watershed-wide vision, toured local sites for a hands-on perspective of different conservation issues, and networked with peers at this event sponsored by the Coalition for the Delaware River Watershed and the William Penn Foundation. The Delaware River Watershed Initiative is part of a \$35 million investment by the William Penn Foundation to protect and restore the 13,000 square miles that provide drinking water in four states to over 15 million people (5% of the nation's population) and the first (New York City) and 7th largest metropolitan economies in the United States. Prominent speakers from Delaware who discussed the economic and ecological value of the Delaware River Watershed to the First State included Governor Jack Markell, Congressman John Carney, DNREC Secretary David Small, and National Wildlife Federation President Collin O'Mara. DWRC Director Gerald Kauffman spoke about "Water Use in the Delaware River Basin" during the opening plenary session.

NIWR Annual Meeting in Washington, DC

National water issues such as the Flint River crisis, Texas flooding, and California drought were the focus of the National Institutes for Water Resources (NIWR) meeting in Washington, DC on February 8-10, 2016 where Gerald Kauffman and Martha Narvaez attended with our colleagues and directors of water resources institutes at 48 land grant universities stretching from Maine to Alaska to Guam and the U.S. Virgin Islands. Near the U.S. Capitol, we discussed the need for approval of the Water Resources Research Act legislation by Congress that would assist our land grant universities in addressing these national water issues in concert with scientists from NOAA, USDA, Interior, USGS, EPA and US Army Corps of Engineers.

Leap Day Meeting of the DWRC Advisory Panel

At a February 29, 2016 special leap-day meeting of the DWRC Advisory Panel, the DWRC Advisory Panel discussed water research and education priorities for Delaware and a poll was distributed requesting the panel to update the priorities (such as Climate Change and Sea Level Rise) and recommend any additional priorities to the list. DWRC Director Dr. Gerald Kauffman also welcomed Dr. Afton Clarke-Sather, Assistant Professor of Geography as the newest member of DWRC Advisory Panel. AWRA National President Martha Narvaez from the DWRC discussed the national priorities of the American Water Resources Association during her 2016 term and discussed natural linkages at the national level between the AWRA and the DWRC and the other 53 land grant universities in the National Institutes for Water Resources (NIWR).

DWRC Advisory Panel

The DWRC Director appointed the following DWRC Advisory Panel for three year terms:

Mr. Jayme Arthurs, USDA Natural Resources Conservation Service, Dover, DE; Mr. Chris Bason, Center for the Inland Bays, Rehoboth, DE; Dr. Afton Clarke-Sather, Dept. of Geography, Univ. of Delaware, Newark, DE; Mr. Tom Coleman, City of Newark Public Works and Water, Newark, DE; Mr. Jeff Downing, Mt. Cuba Center, Wilmington, DE; Ms. Asia Downtin, Ph.D. Candidate, Dept. of Geography, Univ. of Delaware, Newark, DE; Dr. Mingxin Guo, Dept. of Agriculture & Natural Resources, Delaware State Univ., Dover, DE; Ms. LeeAnn Haaf, Partnership for the Delaware Estuary, Wilmington, DE; Mr. Stephen Hokuf, Dept. of Planning, NCC Government Center, New Castle, DE; Dr. Paul Imhoff, Dept. of Civil and Environmental Engineering, Univ. of Delaware; Newark, DE; Dr. Shreeram Inamdar, Dept. of Plant and Soil Sciences, Univ. of Delaware, Newark, DE; Dr. Janet Johnson, Dept. of Political Science, Univ. of Delaware, Newark, DE; Mr. Richie Jones, The Nature Conservancy – Delaware, Wilmington, DE; Dr. Thomas McKenna, Delaware Geological Survey, Univ. of Delaware, Newark, DE; Mr. Matt Miller, Aqua Pennsylvania, Bryn Mawr, PA;

Ms. Martha Narvaez, Delaware Water Resources Center, Univ. of Delaware, Newark, DE; Ms. Ginger North, Delaware Nature Society, Hockessin, DE; Ms. Betzaida (Betzy) Reyes, US Geological Survey, Dover, DE; Mr. Kash Srinivasan, Wilmington, DE; Mr. Robert Struble, Brandywine Valley Association, West Chester, PA; Ms. Jennifer Volk, Kent County Cooperative Extension, Univ. of Delaware, Dover, DE; Ms. Jennifer Walls, Division of Watershed Stewardship, Delaware DNREC, Dover, DE

Annual Activities

The Delaware Water Resources Center receives an annual Federal matching grant authorized by section 104 of the Water Resources Research Act of 1984 (Public Law 98-242) as amended by Public Law 101-397, Public Law 104-147, and Public Law 106-374. The U.S. Geological Survey (USGS), Department of the Interior, administers the Act. This annual evaluation report describes, in the format prescribed by the USGS, research, training, and information transfer activities supported by section 104 grants and required matching funds during fiscal year 2015.

The DWRC has defined a three-fold mission to meet the goals of the Water Resources Research Act:

- (1) To support research that will provide solutions to Delaware's priority water problems;
- (2) To promote the training and education of future water scientists, engineers, and policymakers; and
- (3) To disseminate research results to water managers and the public.

Understanding the nature of the water quality and water supply problems faced in Delaware requires knowledge of the physiography of the state, its climate, and major land uses. Geologically, Delaware sits in the Piedmont and Atlantic Coastal Plain Provinces. Only the northernmost 6% of the state is within the Piedmont, a region created of very old igneous and metamorphic rock. Soils range from well-drained, highly productive silt loams in the Piedmont to well- and excessively well-drained sandy loams and loamy sands in the Coastal Plain. Significant areas of poorly drained soils are also present, particularly in southeastern Delaware. Erosion and surface runoff are the main concerns in the Piedmont, while leaching of contaminants to shallow ground waters is the main water quality problem in the Coastal Plain. Average annual rainfall is plentiful (45 inches/year) and rather constant, averaging 3 to 4 inches/month in winter and spring and 4 to 5 inches/month in summer. Precipitation typically exceeds evapotranspiration by 12 to 18 inches/year, providing 10 to 12 inches/year of ground water infiltration.

Surface water is the main water supply source in the Piedmont, although the Cockeysville Formation is an important local aquifer of fractured marble and dolomite. This province is dominated by the Christina River Basin, fed by rivers that first flow extensively through Pennsylvania and Maryland. Water quality of the White Clay and Red Clay Creeks and Brandywine River is strongly affected by land use and point sources of pollution in neighboring states. Those rivers flow into the Christina River which, in turn, flows into the Delaware River.

Ground water is the major water supply source for the Atlantic Coastal Plain, a province of southeastwardly thickening unconsolidated and semi-consolidated sediments over crystalline basement rock. A primary aquifer in this province for water supply, stream base flow, and confined aquifer recharge is the unconfined Columbia aquifer. In a southwardly expanding wedge, the western portion of this area flows to the Chesapeake Bay through headwaters of the rivers and creeks of the Delmarva Peninsula's eastern shore. The mideast province flows to the Delaware Estuary, fed by the watersheds of 15 creek and river systems. The southwest portion of the state flows into the Inland Bays of Delaware and Maryland and the Atlantic Ocean.

The major land use in Delaware is agriculture (526,070 acres; 41% of the 1.28 million acres in the state), which is dominated by a large, geographically concentrated poultry industry. Other main land uses are urban (19%), wetlands (19%), forests (15%), open water (4%), and barren land (1%). Delaware has 2509 miles of streams and rivers, 2954 acres of lakes/ponds, 841 square miles of estuarine waters, and 25 miles of ocean coastline. Approximately three-quarters of the state's wetlands are freshwater, and one-fourth is tidal.

Protection of the quality and quantity of the state's surface waters and aquifers is a major concern to all agencies and individuals responsible for water resource management in Delaware. Ground water protection is particularly important given the increasing reliance on this resource for drinking water. In general, the key priority water resource issues today are (not prioritized): (1) enhanced management and control of stormwater runoff, erosion and sediment; (2) improved understanding of sources, transport, fate, and remediation of toxic organics and trace elements; (3) comprehensive management of agricultural nutrients and sediment; (4) identifying sources of pathogenic organisms and preventing human health impacts; (5) increased understanding of the response of aquatic systems to pollutants; (6) identification and protection of wellheads and aquifer recharge areas; (7) better management of water supply and demand and development of a systematic means to deal with droughts and floods; (8) treatment and disposal of on-site sewage; (9) protection and restoration of wetlands; (10) prevention of saltwater intrusion to potable water supplies; (11) protection of functioning riparian areas; and (12) climate change impacts on water resources, including water quality and water supply.

Surface Water Quality - The National Pollution Discharge and Elimination System (NPDES) Program in Delaware has reduced the number of individual "point source" permits to discharge wastewater and stormwater from over 200 in the 1970s to 51 as of 2014. Of those, eight are all or almost all stormwater. NPDES permitting programs have been expanded to address pollution in stormwater runoff from concentrated animal feeding operations ("CAFOs," over 400 potential permittees), construction (2250 permittees as of May 2013), and ongoing industrial activities (363 permittees). Current initiatives include implementation of "Total Maximum Daily Load" (TMDL) requirements, in a long term multi-state effort to reduce PCBs in the Delaware River, and implementation of "Best Available Technology" for cooling water intake structures which draw in tens and hundreds of millions of gallons per day of water from Delaware waters. Major reductions in oxygen demanding materials and toxics in surface waters have been achieved. The PCSs and/or WIPs have been completed for the Appoquinimink, Broadkill, Chesapeake Bay, Christina, Inland Bays, Mispillion and Cedar Creek, Murderkill, Nanticoke, St. Jones, and Upper Chesapeake (Chester and Choptank) watersheds.

Urbanization: A rapidly expanding urban population is increasing pressures on Delaware's surface waters. Rivers and streams are being affected by elevated temperature and low dissolved oxygen levels that can result from degradation of streambanks and stream channels. In residential and urban areas, increases in impervious surface have resulted in greater and flashier stormwater runoff, leading, in turn, to erosion, sedimentation, shallower water levels and destabilization of stream channels. Biological and habitat quality are also being affected by removal of stream buffers and stream bank "hardening" through use of riprap and concrete.

Drainage: Extensive drainage systems have been installed throughout the state, especially in coastal plain areas. Most were constructed in the 1930s and 1940s by the Civilian Conservation Corps and the Works Progress Administration. At that time, building a drainage ditch system involved channelizing and straightening headwaters of existing natural streams, then constructing ditches out and back from the channelized stream. Upland wetlands were often drained to reduce mosquito populations.

Nutrients: Nutrients are a leading cause of water quality degradation in Delaware. Nutrient effects can be seen especially in lakes, ponds, bays, and estuaries that receive nutrients conveyed by rivers, streams, and ground water. Primary land-based sources of nutrients in Delaware are agricultural practices, septic systems, and urban runoff. About 41% of Delaware's land area is devoted to agricultural activities and 19% to urbanized

uses. Delaware's agricultural industry has a strong broiler industry component that heavily influences the state's overall agricultural nutrient balance and has long created nutrient management problems because of the large amount of manure that must be land applied; commercial inorganic fertilizers used by farmers, other land managers and homeowners also contribute nutrients to ground and surface waters. About 70% of Delaware's cash farm income comes from broilers, with annual production ranging from 260 to 280 million broilers, primarily in Sussex County, the largest broiler chicken producing county in the U.S.

Toxics: Toxics have affected Delaware waters resulting in fish consumption advisories for the Delaware River and Bay, Atlantic coastal waters including the Inland Bays, and twenty smaller waterbodies in 2009. The primary pollutant is polychlorinated biphenyl (PCB). Chlorinated pesticides, dioxins, and mercury have also been identified. Though PCBs have long been banned, they are persistent in the environment and are transported from land to waters through runoff. New designated uses and surface water quality standards as amended on July 11, 2004 indicate that pathogenic organisms in surface waters have negatively affected shellfish harvesting and caused 86% of Delaware's rivers and streams to not fully support the swimming use; 98% do not fully support the fish and wildlife use. Most waters do not meet standards because of nonpoint source pollution impacts. In 2012 the Department of Natural Resources developed a "Watershed Approach to Toxics Assessment and Restoration" (WATAR), a five-year plan to integrate and coordinate assessment and restoration of watersheds impacted by toxics.

Ground Water Quality - The domestic needs of approximately two-thirds of the State's population are met with ground water provided by both public and private wells. Most of the water used for agriculture, Delaware's largest industry, and self-supplied industrial use, is also derived from ground water sources. A shallow water table and highly permeable soils make Delaware's ground water vulnerable to pollution. Shallow unconfined aquifers are especially vulnerable, though deeper confined aquifers are susceptible as well because they subcrop beneath and are recharged by unconfined aquifers. Major ground water quality problems in Delaware today are:

Nutrients: Nitrates from agriculture and septic systems are, by far, the major contaminant in Delaware's ground water. There are also some concerns about dissolved phosphorus transport to surface waters by shallow ground water flow in parts of the state where shallow water tables are interconnected with surface waters by ditches and/or tiles.

Organics: Hydrocarbons have also been found as have pesticides, though not at levels which cause alarm. A major source of hydrocarbons, such as MBTE, is leaking underground storage tanks (USTs) while agricultural activities are the source of pesticides. There are 12,050 regulated underground storage tanks in the State; 9651 have been properly abandoned and 2399 are still in use. Over the period 2002-2003, 142 sites had confirmed releases with 30 confirmed ground water releases.

Saltwater Intrusion: Problems with private wells occur sporadically from seasonal saltwater intrusion along the Delaware River and the Inland Bays/Atlantic Ocean coastal areas.

Trace Elements: Though not considered a health threat, iron concentrations are a widespread problem in Delaware for cosmetic reasons. Many public water supplies have treatment systems to remove iron. Thirty-four percent of 561 raw ground water samples analyzed by Delaware's Office of Drinking Water in 2002 exceeded the secondary contaminant level standard of 0.3 mg/L. Concerns exist about arsenic in ground waters because of the long-term application of this element in poultry manure to soils overlying shallow drinking water aquifers, the presence of brownfield soils in urban areas that had been used as tanneries or other industries, and the lowered drinking water standard for arsenic.

Wetlands: The ambient condition of fresh and salt water wetlands was assessed in the Broadkill, Cedar Creek, Mispillion, Little River and Leipsic watersheds. Scientific reports summarizing the condition of existing

wetlands, recent changes in wetland acreage and land use, and management recommendations were created for the Broadkill watershed. Reports and related information can be found on the Delaware Wetlands webpage: <http://de.gov/delawarewetlands>,

Water Supply - Half of Delaware's population is located in the Piedmont (6% of land area) and uses surface water for drinking water. The other 50% of the population relies on ground water and is spread throughout the remaining 94% of the State. With regard to the amount of water used, ground and surface water are of equal importance; with regard to area served, ground water is overwhelmingly dominant. Capacity concerns are important north of the Christina River due to population concentration and the reliance on surface water. For the rest of the state, the reliance on abundant ground water and a diffuse pattern of development suggest that the supply of potable water is not currently a problem. Recent drought emergencies have brought water supply demand in northern Delaware into conflict with the need to maintain minimum pass-through flows in streams for protection of aquatic resources. Benthic organisms, the foundation of the aquatic food chain, cannot move to avoid dry stream bed conditions. This suggests that not maintaining pass-through flows at all times would be detrimental to stream aquatic life. Required pass-through flows can be high; the need to ensure those flows can result in practices or structures such as reservoirs that are economically inhibitory or may cause as much or greater environmental degradation as occasional dry stream bed periods.

Stream and Wetland Restoration - Rehabilitating stream corridors by re-establishing natural floodplains and sinuous low-flow channels, stabilizing stream banks, decreasing erosion, improving water quality, increasing wildlife habitat, providing buffers along the streams, establishing wetlands, promoting ground-water recharge and water storage, controlling invasive plant species, reintroducing native plant species, and reducing turbidity and sediment loading into stream channels are examples of the benefits that result from projects DNREC has implemented to improve the ecological quality and biological diversity in the State's watersheds. Over the past few years, stream restoration projects have been completed along Mill Creek, Ham Run (tributary to Red Clay Creek), Middle Run (tributary to White Clay Creek) and Silver Lake Park (tributary to Appoquinimink River in Middletown) in New Castle County and along the St. Jones River in Dover (Kent County) at the Silver Lake Park and Mirror Lake projects.

Source Water Assessment and Protection - The DNREC Source Water Assessment and Protection Program (SWAPP) provides for the assessment and protection of sources of public drinking water, both surface and ground water. The assessment consists of three critical steps: first, delineation of source water areas; second, identification of existing and potential sources of contamination; and finally, assessment of the susceptibility of the source water area to contamination. The Site Index Database identifies the location and status of both existing and potential sources of contamination within the State. Most potential point sources have been mapped and rated. In 2004, the Source Water Protection Program developed a guidance manual for local governments. This document was updated in 2005. A citizen's advisory group (CTAC) was formed to assist DNREC in the development and implementation of the program and to ensure public involvement. SWAPP is a multi-phase program that is expected to be completed in the next few years.

Cooperative Efforts - Cooperation among DNREC, residents, other agencies-state and federal, universities, county and municipal governments, conservation districts, and non-governmental organizations (NGOs) helps bring Delaware water goals to fruition. Pollution Control Strategy development and implementation of TMDL regulations is driven by Tributary Action Teams (TATs). The Center for the Inland Bays, Nanticoke Watershed Alliance, Partnership for the Delaware Estuary, Delaware Nature Society, University of Delaware Cooperative Extension, the Sea Grant Program at the University of Delaware College of Earth, Ocean, and Environment, Delaware State Cooperative Extension, the Camden-Wyoming Rotary Club, the State of Delaware's Nutrient Management Commission, New Castle, Kent and Sussex County governments, Sierra Club, the county conservation districts, USDA, USGS other DNREC divisions and many others have been vital contributors in the development and implementation of PCSs and WIPs.

Research Program Introduction

At a February 29, 2016 special leap-day meeting of the DWRC Advisory Panel, we heard presentations on the work of our graduate research assistants and undergraduate interns supported by DWRC, who put on display an impressive body of research. Over the last year the DWRC has sponsored the research of 21 students (two graduate and nineteen undergraduate) who joined with faculty advisors in four colleges to work on addressing the water resources problems of tomorrow. The future of water resources is in good hands with this cohort of budding water scientists and the DWRC is poised to address the water challenges in Delaware, the Delmarva, and indeed nationally and globally. The DWRC Advisory Panel reviewed the following student presentations and recommended continued funding for graduate students Lauren Lechner and Daniel Sanchez-Carretero. Undergraduate students Ryan Hall, Margaret Orr, and Jillian Matz went on to present posters at UD's Celebration of Undergraduate Engaged Scholarship in April 2016.

Lauren Lechner, advisor Dr. Pei Chiu (Dept. of Civil and Environmental Engineering, UD College of Engineering), Removal of Phosphate from Water Using Scrap Iron

Daniel Sanchez Carretero, advisor Dr. C.P. Huang (Dept. of Civil and Environmental Engineering, UD College of Engineering), Electrochemical Reduction of Carbon Dioxide

Ryan Hall, advisor Dr. Paul Imhoff, Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nitrogen Treatment of Stormwater Runoff

Margaret Orr and Jillian Matz, advisor Dr. Shreeram Inamdar, Water Workings at Fair Hill Nature Resource Mgmt. Area: Rainfall, Sedimentation/Rapid Changes in Stream Water Quality

The DWRC Advisory Panel completed a survey and then updated the list of DWRC water research priorities as follows, with [1] being the highest priority (score listed after each priority):

[1] Water quality (nutrients, pathogens, and public health) (12.6); [2] Storm water runoff (management and control) (11.3); [3] Water pollutants (sources, fate, cycling, and transport) (10.6); [4] Water supply, demand, conservation (infrastructure) (9.7); [5] Water policy (governance and economics) (9.3); [6] Climate change (variability) (8.4); [7] Groundwater (remediation and treatment) (8.3); [8] Watershed management (8.3); [9] Wetlands (protection and restoration) (7.5); [10] Wastewater management (treatment and reuse) (7.4); [11] Water, food, and energy nexus (7.3); [12] Sea level rise (6.9); [13] Coastal flooding (4.9); [14] Estuary processes (4.4); [15] Water resource topics in marine studies (4.4).

UD Undergraduate Research Poster Session

On April 29, 2016, nineteen DWRC undergraduate students, funded from mid-2015 through February 2016, presented research posters at the Celebration of Undergraduate Engaged Scholarship at the University of Delaware Perkins Student Center. DWRC undergraduate water research internships are funded by the U.S. Geological Survey and the State Water Resources Research Institute (WRRI) Program, authorized by section 104 of the Water Resources Research Act of 1984.

Samuel Dever (Environmental Engineering), Advisor: Paul Imhoff (Civil and Environmental Engineering), Water Retention and Mineral Weathering in a Forest Catchment

Nicole Golomb (International Relations), Advisor: Philip Barnes (Public Policy), Delaware Database for Funding Resilient Communities (DDFRC)

Research Program Introduction

Xiaolun Guo (Environmental Engineering), Advisor: Chin-Pao Huang (Civil and Environmental Engineering), Impact of Climate Change on Water Quality: Effect of Temperature on the Kinetics and Thermodynamics of Mineral Solubility

Ryan Hall (Environmental Engineering), Advisor: Paul Imhoff (Civil and Environmental Engineering), Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nitrogen Treatment of Stormwater Runoff

James Hanes (Environmental Science), Advisor: A. Scott Andres (Delaware Geological Survey), Determination of Daily Net Primary Production from Continuous Water Quality Monitoring in the Surface Waters of Coursey Pond, Delaware

Kelli Kearns (Environmental Engineering), Advisor: Angelia Seyfferth (Plant and Soil Sciences), Comparison of Greenhouse Gas Fluxes from Two Flooded, Vegetative Environments

Andres Kwart (Environmental Engineering), Advisor: Anastasia Chirnside (Entomology and Wildlife Ecology), Evaluation of a Fungal Solid State Bio-Reactor to Reduce Pollutant Concentration in Food Processing Wastewater

Alyssa Lutgen (Environmental Science), Advisor: Delphis Levia (Geography), The Isotopic Composition of Throughfall in Relation to Drop Size Diameter Distribution

Jillian Matz (Environmental Science), Advisor: Shreeram Inamdar (Plant and Soil Sciences), Diel Patterns in Dissolved Organic Matter in a Forested Headwater Catchment in Maryland

Marcos Miranda (Environmental Engineering), Advisor: Daniel Cha (Civil and Environmental Engineering), Breathable Membrane Enclosures for Fecal Sludge Stabilization: Application in Eco-vapor Toilets

Adam Nesbitt (Energy and Environmental Policy), Advisor: Lawrence Agbemabiese (Energy and Environmental Policy), Potential for the Delaware Sustainable Energy Utility to Invest in Clean Water

Margaret Orr (Meteorology and Climatology), Advisor: Shreeram Inamdar (Plant and Soil Sciences), Relating Rainfall Intensity to Sediment Mobilization at Fair Hill

Erica Rossetti (Natural Resource Management) and Samantha Serratore (Environmental Engineering), Advisor: Gerald Kauffman (Public Policy), Brandywine-Piedmont Watershed Plan: First State National Park

Nicholas Villari (Plant and Soil Sciences), Advisor: Amy Shober (Plant and Soil Sciences), Understanding the Role of Ditch Sediments in the Transport of Phosphorus in Agricultural Drainage on the Delmarva

Ha Vu (Chemistry), Advisor: Deb Jaisi (Plant and Soil Sciences), Application of P31 NMR Spectroscopy to Understand Phosphorus Speciation in Wastewater

Gemma Antoniewicz, Norma Brasure, and Clare Sevcik (Environmental Science and Environmental Engineering), Advisor: Gerald Kauffman (Public Policy), The DWRC UD WATER Program: Silver Brook Watershed Plan

State Water Resources Research Institute Program, Delaware Water Resources Center, Annual Proposal for Fiscal Year 2015

Basic Information

Title:	State Water Resources Research Institute Program, Delaware Water Resources Center, Annual Proposal for Fiscal Year 2015
Project Number:	2015DE274B
Start Date:	3/1/2015
End Date:	2/29/2016
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Congressional District:	DE-001
Research Category:	Water Quality
Focus Category:	Water Quality, Water Supply, Ecology
Descriptors:	None
Principal Investigators:	Gerald Joseph Kauffman

Publications

1. Dever, S., and P. Imhoff, 2016, Water Retention and Mineral Weathering in a Forest Catchment, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.
2. Golomb, N., and P. Barnes, 2016, Delaware Database for Funding Resilient Communities (DDFRC), Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.
3. Guo, X., and C.-P. Huang, 2016, Impact of Climate Change on Water Quality: Effect of Temperature and Particle Size on the Kinetics and Thermodynamics of Mineral Solubility, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 23 pages.
4. Hall, R., and P. Imhoff, 2016, Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nitrogen Treatment of Stormwater Runoff, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 14 pages.
5. Hanes, J., and A.S. Andres, 2016, Rates of Net Primary Production from Continuous High-frequency Monitoring of Coursey Pond, Delaware, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 21 pages.
6. Kearns, K., and A. Seyfferth, 2016, Comparison of Greenhouse Gas Fluxes from Two Flooded, Vegetative Environments, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 7 pages.
7. Kwart, A., and A. Chirnside, 2016, Evaluation of a Fungal Solid State Bio-Reactor to Reduce Pollutant Concentration in Food Processing Wastewater, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 2 pages.
8. Lutgen, A., and D. Levina, 2016, The Isotopic Composition of Throughfall in Relation to Drop Size Diameter Distribution, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 8 pages.
9. Matz, J., and S. Inamdar, 2016, Diel Patterns in Dissolved Organic Matter in a Forested Headwater Catchment in Maryland, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 5 pages.

10. Miranda, M., and D. Cha, 2016, Breathable Membrane Enclosures for Fecal Sludge Stabilization: Application in Eco-vapor Toilets, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 10 pages.
11. Nesbitt, A., and L. Agbemabiese, 2016, Potential for the Delaware Sustainable Energy Utility to Invest in Clean Water, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 53 pages.
12. Orr, M., and S. Inamdar, 2016, Relating Rainfall Intensity to Sediment Mobilization at Fair Hill, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 10 pages.
13. Rossetti, E., S. Serratore, and G. Kauffman, 2016, Water Quality Sampling Field Report: First State National Park Brandywine-Piedmont Watershed Plan, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 60 pages.
14. Villari, N., and A. Shober, 2016, Understanding the Role of Ditch Sediments in the Transport of Phosphorus in Agriculture Drainage on the Delmarva, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 13 pages.
15. Vu, H., and D. Jaisi, 2016, Application of P31 NMR Spectroscopy to Understand Phosphorus Speciation in Wastewater, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 14 pages.

Photoelectrochemical Oxidation of PPCPs in Water and Electrochemical Reduction of Dissolved Carbon Dioxide in Water to Hydrocarbons

Department of Civil and Environmental Department

Student: Daniel Sanchez Carretero

Advisor: Professor C. P. Huang

1. Background and Justification

In the last decades, and especially in developed countries, there has been an increasing release of pharmaceutical and personal care products (PPCPs) into the water environment, affecting the water quality worldwide¹. The persistence of these chemicals makes them hard to be removed from wastewaters in sewage treatment^{2,3}. There has been a recording of data⁴ from the literature about the types of PPCP found in the waters in WWTPs including hormones such as estrone, estriol, testosterone and progesterone, and analgesic-anti-inflammatories such as ibuprofen, diclofenac, naproxen, ketoprofen and mefenamic acid.

In order to deal with this water quality deterioration, technology, especially “green” and cheap is needed to treat these contaminants. Both biodegradation and chemical treatments have been used, especially the ones that transform the contaminants chemically and render them as non-toxic. Biodegradation, because of its cost-effectiveness and versatility in handling a wide variety of pollutants, is the common treatment process. However, many PPCP can't be treated using this method^{5,6}. Other methods, like thermal destruction are effective in destroying the targeted chemicals but they are far too expensive and can't be always applied in water systems since they evaporate the water before destroying the chemicals.

Advanced chemical oxidation processes (AOP) are reactions that change the oxidation state of the key element of recalcitrant organic chemicals by strong oxidizing agents⁷. The most common way is based on the addition of ozone or hydrogen peroxide in the presence of ultraviolet light or catalysts, but this method involves the addition of chemicals into the WWTPs. However, heterogeneous photocatalysis, in which the major source of energy is derived from sunlight, has been prompted. The concerning issue is that, TiO_2 , the main photocatalyst used in these processes has a band gap of 365-388nm, located at the unworkable bottom of the light solar spectrum, that, in addition with a fast electron-hole recombination, decreases its photocatalytic quantum yield.

The photoelectrochemical process proposed in this research will allow the instantaneous separation of electrons and holes generated photocatalytically and enable the holes to oxidize the selected PPCP while the electrons will be used to chemically reduce the compound in the cathodic chamber, in this case CO_2 , to readily useful hydrocarbons.

Since the beginning of the industrial revolution, massive amounts of CO_2 have been released from factories, vehicles and energy stations, causing a rise of CO_2 levels in the atmosphere. In addition to the pollution issue and the health concerns related to the presence of excess CO_2 in the air⁸, CO_2 is also known for causing a positive effect in the heat retention of the atmosphere, taking then, part in global warming⁹.

On the other hand, more than 80% of the energy consumed by the U.S. has been produced from hydrocarbon fuels such as coal, natural gas and petroleum¹⁰. Because of this, and the energetic properties of hydrocarbons such as high energy density, easy transportation and stability¹⁰, it is of interest to find new methods that will readily provide this kind of fuels for future use.

Electrochemical reduction of water dissolved CO₂ provides a solution to both the environmental and energetic issues. The transformation of CO₂ and water into hydrocarbons decreases the amounts of CO₂ in the environment and generates a ready-to-use energy source.

In order to successfully achieve a nonpolluting water treatment process, the energy source for the electrochemical reduction must come from a renewable source of energy. Otherwise, if the energy needed for the electrochemical reduction were obtained from hydrocarbons, there wouldn't be a clear net benefit for the environment. This is why the photoelectrochemical oxidation of PPCP is of such interest in this case. Electrochemical reduction of CO₂ to hydrocarbons would, in a way, allow for storage of the solar energy in form of chemical energy, which would eliminate the need of batteries for its storage, like most solar cells do. For this reason, the produced hydrocarbons have been coined with the term of "Solar Fuels".

There has been research on electrochemical reduction of CO₂ since the 1950's even though it was not too successful due to the Mercury electrodes used in the process¹¹. Years later, around the 1980's Hori et al. published a paper proving the exceptional ability of copper electrodes in the selectivity of hydrocarbons due to electrochemical reduction of CO₂ dissolved in water¹². The issue that scientists and engineers have been facing these last decades is the low selectivity that the electrode shows towards a certain type of hydrocarbon.

2.0 Objectives

There are three main objectives in this research, starting from the synthesization of photocatalysts for the electrochemical oxidation of hazardous organic compounds to the study of the reduction of CO₂ to the selected hydrocarbons.

TiO₂ nanoparticles present the advantage of being a cheap, non-toxic photocatalyst, but its large band gap makes it transparent to visible light and almost inefficient at the solar spectrum. Reducing the band gap will make the photocatalyst sensible to visible light, and therefore more efficient in the solar spectrum. This can be achieved by controlling the particle size^{13,14} or adding impurities to the TiO₂ nanoparticles^{15,16}.

The oxidation of the selected PPCP and the factors that affect it such as pH, concentration of organic compounds, intensity and wavelength of the light source, presence of water cations (Ca²⁺ and Mg²⁺) and anions (bicarbonate, sulfate, nitrate and chloride), biased potential and dissolved organic matter will be studied.

The study of the properties of copper electrodes in the electrochemical reduction of CO₂ in order to find a mechanism that will allow for a better selectivity towards a certain type of hydrocarbon, in our case, formic acid. Plenty of surface characteristics can be modified in order to accomplish such goal; composition, surface structure and crystalline facet orientation. In this research experimental results along with theoretical calculations using Density Functional Theory (DFT) will be used to find such mechanism.

3.0 Methodology

The 3D TiO₂ photoanodes will be prepared by the method explained in the submitted proposal. First, ITO nanowire arrays are prepared by electronic deposition. Then the ITO sol will be subjected to an electric field with a Pt mesh as the anode. The length of the

template growth ITO nanowires will be controlled by deposition time. Finally, layers of TiO_2 will be coated on top of the ITO nanowires by applying a layer of amorphous sol to the ITO arrays. The coating will be dried at room temperature first, and then at 450°C to an approximate thickness of 5-25nm.

The photoelectrochemical oxidation and reduction of the compounds will be conducted using a two-chambered photoelectrochemical (PEC) reactor. Both chambers will be connected through an opening containing a cation exchange membrane (CEM), allowing only H^+ to go from the anodic chamber to the cathodic chamber. The anodic chamber will contain a quartz window that will allow for the complete transmission of light from the source to the photoanode made from the newly prepared TiO_2 nanophotocatalysts. Connecting the photoanode and cathode, there will be a small biased potential that will prevent the electron-hole pairs from recombining and therefore increasing the faradaic efficiency of the system. The selected PPCP for the anodic chamber are triclosan, ketoprofen, carbamazepine and sulfapyridine. Such PPCP have been chosen because of its persistence in WWPTs due to its resistance to removal by ozonation¹⁷.

Different variables in the electrolyte in both chambers will be modified in order to achieve the higher oxidation and reduction efficiencies such as pH, concentration of electrolyte and other ions in the solution. Another important part of the modifications will be done on the electrodes, to acquire the highest absorption and electron transfer coefficients. The copper cathode is a good adsorbent of CO_2 and can easily reduce the carbon^{18,19}. However, other metals have to be deposited onto the electrode in order to create bonding sites for the reduction of water to obtain the required elements for the creation of hydrocarbons²⁰ Different transition metals will be deposited onto the copper surface to

facilitate oxygen disassociation near the CO₂ adsorption sites that will then recombine to create formic acid (CH₃OH).

4.0 Progress to date:

On this first part of the project there was an extensive literature review on the role of copper electrode surfaces in the adsorption and reduction of CO₂. Factors affecting the reactivity of surfaces for both electrodes were studied as well as their selectivity by the presence of specific defects. Experimental papers on electrode adsorption and heterogeneous catalysis^{18,19} gave an insight about the metals to be deposited onto the electrodes, specially platinum. Theoretical papers, mainly using quantum mechanical software based on density functional theory^{21,22} predicted the most likely pathway of the CO₂ reduction. However, these papers only take into account the gas/solid interphase due to the difficulty of modeling water molecules and their behavior close to charged solid surfaces.

Theoretical papers only explain the event partially due to the complexity of water molecules in such surfaces. Water can polarize molecules close to the surfaces and block adsorption sites. Also, water close to the electrode surfaces completely changes the properties the system, especially close to charged surfaces where the electric field is so strong. Nevertheless, the results produced experimentally will be compared to the theoretical ones and study why they agree or not.

On the first part of this project, training and classes were taken, which included a Quantum Mechanics course to further understand the nature of band gap engineering and how to decrease it for the photoelectrochemical applications discussed earlier; a Practical Electron Microscopy course that provided with the tools to characterize the electrodes to the nanometer scale; a Chemical Aspects of Environmental Engineering course involving the role of pH and pE in aquatic systems in order to study their influence on reduction and oxidation processes and two classes involving the physical and chemical phenomena near surfaces, such as adsorption and electron exchanges: Physical Aspects of Environmental Engineering, and Physics and Chemistry of Surfaces and Interfaces and a NMR Spectroscopy course that provided the tools for hydrocarbon classification. Following the preliminary training, the preparation and study of the electrodes used in the cathodic chamber for CO₂ reduction was conducted.

The raw electrode material chosen for the preparation of cathodes was a copper mesh with 100 x 100 holes per square inch and a wire diameter of 0.0045" as shown in figure 1. A preliminary study was done on the copper electrode by running a cyclic voltammetry under an inert sodium perchlorate electrolyte and a CO₂ saturated electrolyte based on a CO₂ bubbled 0.1M solution of KHCO₃ for 20 minutes as shown in figure 2. The first cyclic voltammetry showed the oxidation and reduction characteristics of the copper atoms in the copper mesh electrode, and the second voltammetry showed the characteristics of absorption and reduction of the CO₂ saturated solution under certain potentials. The cyclic voltammetry was run using a PINE AFRDE4 Potentiostat with a Saturated Calomel Electrode (SCE) and a Platinum counter electrode.

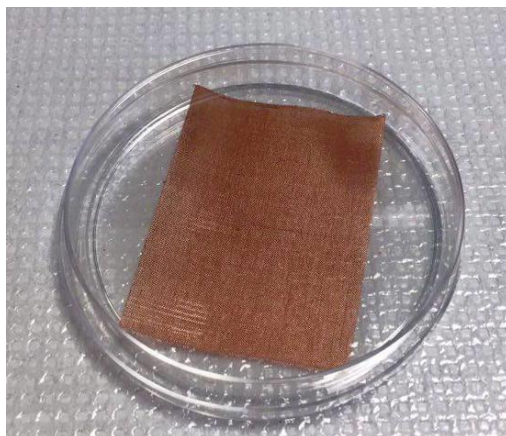


Figure 1: Raw copper mesh electrode

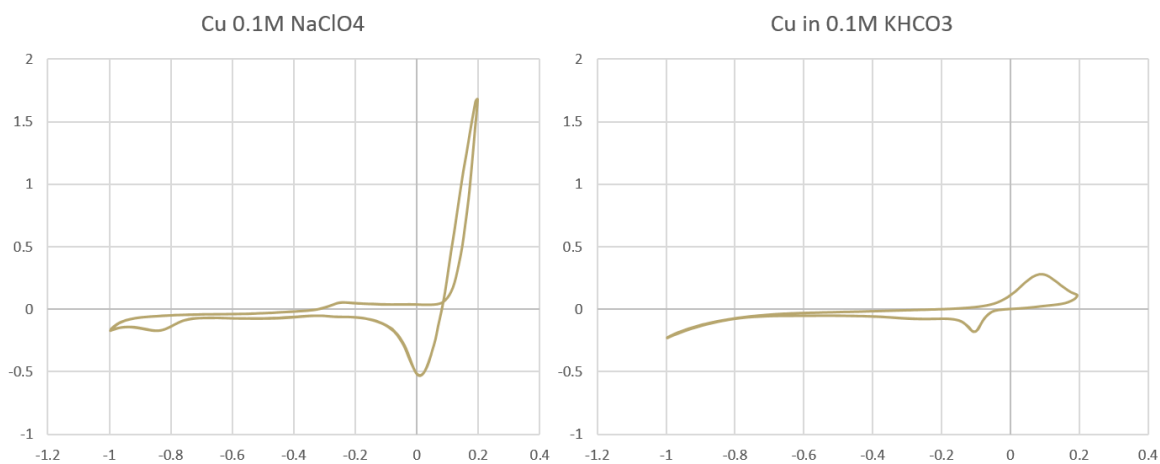


Figure 2: Comparison of cyclic voltammetries on Copper electrode with different electrolytes

Both cyclic voltammetries show different characteristics of the system. On the first one, we are able to see the reduction and oxidation peaks of the copper electrode at different potentials, which helps us identify at what state the electrode should be depending on what potential is applied in our electrochemical cell. On the other hand, the CO₂ saturated system, shows how the CO₂ reacts with the copper electrode at different potentials. For the

CO₂ saturated CV, only a small reduction peak is present at about -0.1V (vs. SCE) which shows that some of the CO₂ present in the solution is being reduced, and oxidized again at around 0.1V (vs. SCE).

Once the initial study of the electrode was conducted, different modifications were done so that different electrode behaviors could be studied and used in our experiment. The method used for modifying our electrodes was an electrodeposition technique, using a two electrode system in a solution with the targeted cations. In this system, the electrode that had to be modified (Copper mesh), was connected to the cathodic part of the system while a graphite electrode was used as the anode. As Shown in figure 3, the cations present in the solution are driven to the cathode and electrochemically deposited onto the copper surface through electronic bonding. This method is useful for many reasons, it uses the least amount of chemicals, the deposition rate can be controlled and the amount of the transition metal deposited onto the copper electrode can be determined easily.

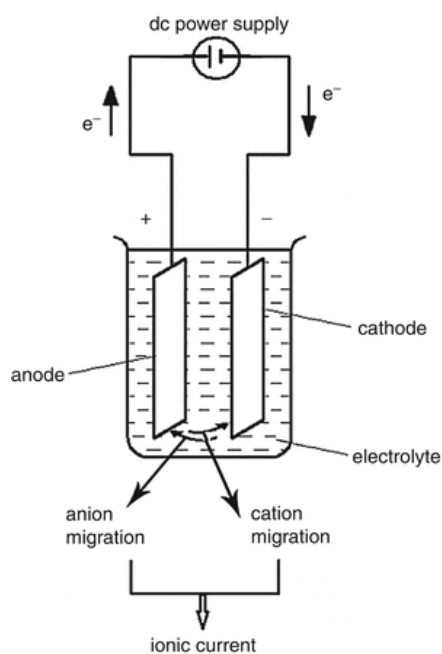


Figure 3: Diagram of the electrodeposition technique used to modify the targeted electrode

Two different transition metals were chosen to modify two different plane copper meshes. Due to the CO₂ adsorbing capacities of copper, the purpose of the second transition metal was to enhance the reduction of the adsorbed molecules through higher mobility or hydrogenating capacities. For this reason, Rhodium, a well-known hydrogenator was chosen to be the second component of this bimetallic electrode catalyst. The electrodeposition was done under a Rhodium Chloride (RhCl₃) saturated solution with a current of 0.3A for 2 minutes. During this deposition time, some current was lost in the generation of oxygen gas due to the relatively high potential applied for the deposition (3V), therefore the amount of Rhodium can't be determined just yet based on current premises. Further experiments will determine the amount of Rhodium deposited onto the copper mesh. After the deposition both cyclic voltammetries were conducted as shown in figure 4.

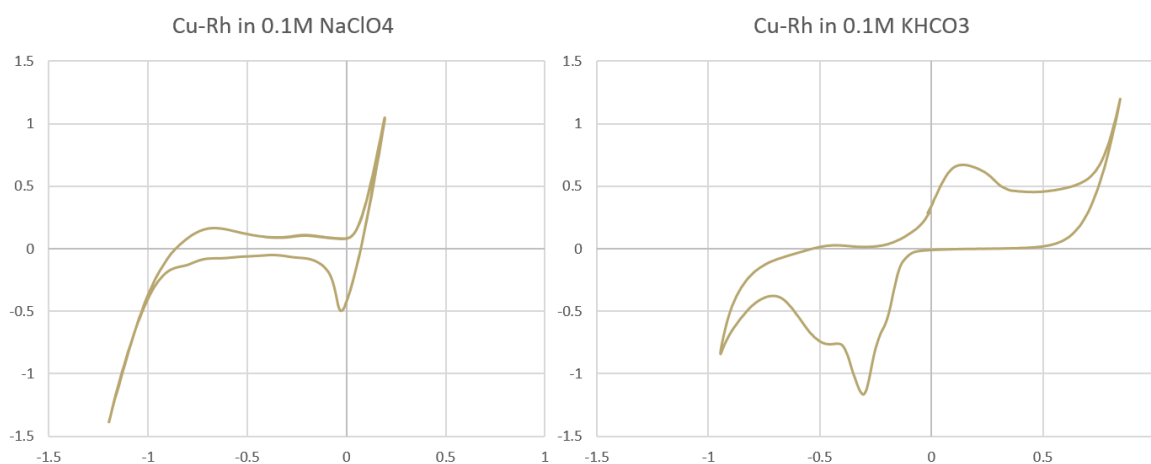


Figure 4: Cyclic voltammetries of Cu-Rh in an inert electrolyte and a CO₂ saturated electrolyte

Both cyclic voltammetries show interesting results when comparing both electrolytes. In the case of a plane copper electrode (figure 2), the current is smaller in the CO₂ containing electrolyte whereas in the case of the Cu-Rh bimetallic catalyst, the current is substantially larger when using the CO₂ containing electrolyte with respect to the inert electrolyte. These results show that the newly generated bimetallic electrode is a promising catalyst for the reduction of CO₂ in aquatic conditions.

However, the scarcity and high price of Rhodium led us to investigate further in different transition metals with similar properties. The first metal that came to mind, with a similar electronic structure but cheaper price and more abundance, Cobalt was chosen to be the potential substitute. The same electrodeposition method was conducted for the same time and at the same current (0.3A for 2 minutes), and the cyclic voltammetries were applied to the newly generate Cu-Co electrode as shown in figure 5.

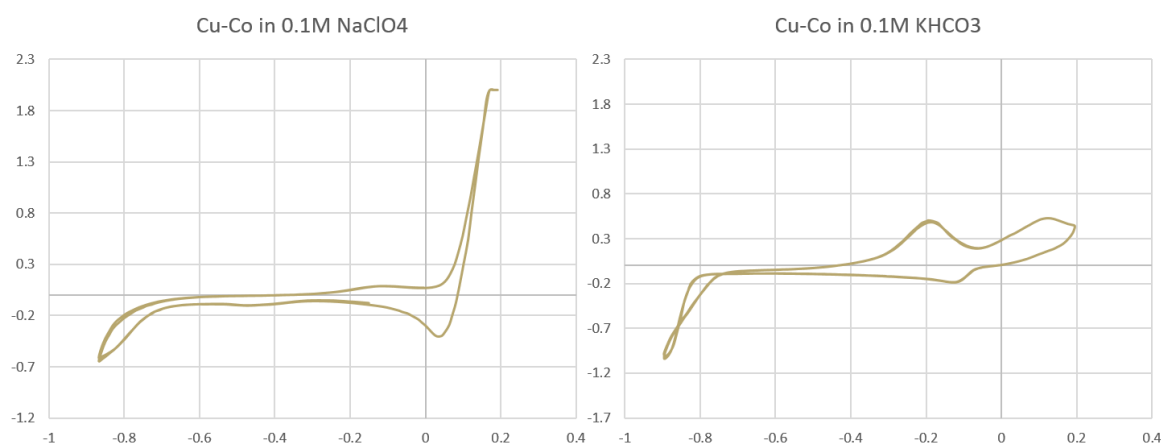


Figure 5: Cyclic voltammetries of Cu-Co in an inert electrolyte and a CO₂ saturated electrolyte

As can be seen from the cyclic voltammetries, Cobalt deposited onto the copper electrode shows two notable advantages from the current efficiency point of view. The first one, is deduced easily when looking at the reduction peak at -0.1 V vs SCE. If we go back to figure 4, it can be seen that the first peak appears at about -0.3 V vs SCE. From this comparison, we can show that CO₂ reduction can be achieved with lower potential differences using a Cu-Co bimetallic catalyst. The peak height is about -0.2 normalized units, whereas for Rhodium the peak goes down to -1.2 units. This sixfold increase in current is substantial, but the price of Rhodium is about 900 times more expensive than that of Cobalt. There needs to be further experimentation and analysis dealing with the amount

of transition metal deposited onto each electrode as well as surface area, factors that will affect current peaks in cyclic voltammetries.

5.0 Research activities for the next 6 months:

The next step in the process, is to fully understand how the electrodeposition technique used to modify our electrodes works. The idea is to understand what is the deposition current efficiency and also how the transition metal atoms rearrange themselves on the surface of the copper mesh. Once this is understood, an objective comparison between the different electrodes will be made. In addition to the current efficiencies, the second parameter that has to be tackled and will lead to modification on our electrodes, is the product selectivity. In the next 6 months, an exhaustive analysis of chemicals produced from the reduction of CO_2 will be done. The experiments will be conducted in a two chambered chemical reactor with a sealed cathodic chamber that will allow for the collection of gas products and a cation exchange membrane to separate the two chambers and seen in figure 6. The collection of gases will be done in a sealed bag in order to prevent pressure from building up inside the reactor. The analysis of both the liquid and gas products will be done on a GC-MS that will identify the nature of the products as well as their concentration. Once, the products are identified, an adjustment of reduction potentials as well as electrode composition will be conducted in order to obtain the most selective and efficient bimetallic electrode possible.

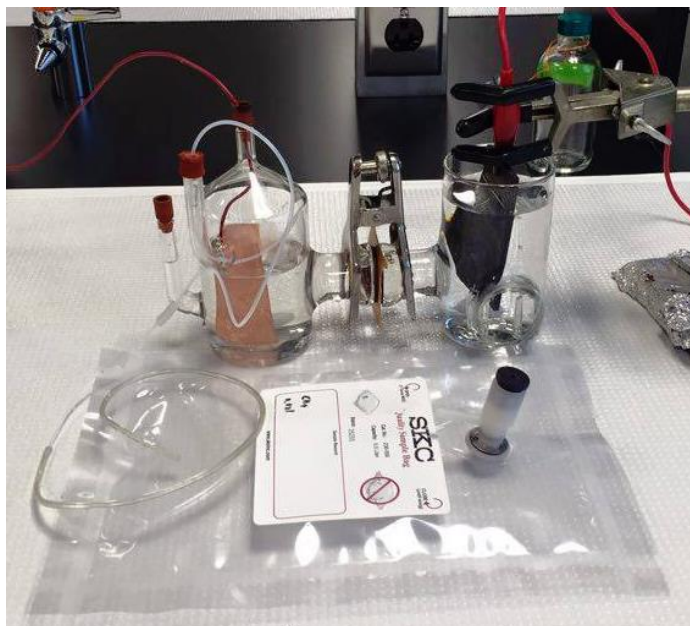


Figure 6: Two-chambered reactor and gas collecting sealed bag

6.0 Conclusion and project implications

The proposed research allows for the treatment of hazardous chemicals such as PPCP by photoelectrochemical oxidation and the generation of hydrocarbons by reducing CO_2 dissolved in water. The energy for the oxidation is collected by the photoelectrocatalysts present in the photoanode that transform the solar light into electron-hole pairs that are used for both oxidation of PPCP and reduction of CO_2 . Only a small amount of external energy is needed to transport the electrons from the photoanode to the cathode. The overwhelming presence of these persistent hazardous chemicals will be reduced with this treatment. The photocatalysts are made so that anyone anywhere in the world can recreate this experiment as long as there is solar light, making it cheaper and cleaner than regular electrochemical processes. In addition to the treatment of waters, this experiment also allows for the creation of hydrocarbon fuels that can also be used to generate energy for any other purpose as needed.

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Project Title: Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron

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Advisor: Dr. Pei Chiu

June 2, 2016

Abstract:

Nutrient removal from water sources is becoming increasingly important, as nutrient pollution is emerging as a challenging and critical environmental issue. Nutrient pollution (excess nitrogen and phosphorus) can cause algal blooms, human health issues, and ecological and economic losses. Stormwater runoff can aggravate this issue, because it easily carries pollutants from surfaces into storm sewer systems and is discharged, untreated, to water sources. This work focuses on removal of phosphorus using scrap iron, or, zero valent iron (ZVI). ZVI has numerous applications in removal technologies, and in this case, can be used as an amendment into a bio retention system to treat stormwater. By using several flow-through column studies, we were able to assess the removal efficiency of phosphorus by ZVI, by using the advection-dispersion-reaction equation to confirm our observational data. It was determined that ZVI can remove approximately 100% of influent phosphorus at the lowest concentration of phosphorus used. This has great promise as an amendment into the field for the treatment of excess phosphorus in stormwater.

1.1 Background/Justification:

Nutrient pollution is a challenging environmental issue that the U.S. is faced with, especially since this leads to polluted bays, rivers, and groundwater. Nutrient pollution is caused by excess nitrogen and/or phosphorus present in the water. This excess can cause harmful algal blooms, human health concerns, and economic and ecological losses (U.S. EPA, 2015). Specifically, in Delaware, the Chesapeake Bay is in poor condition due to nutrient pollution, which results from urban, suburban and agricultural runoff, wastewater treatment plant effluent, and air pollution (Chesapeake Bay Program, 2012). In order to treat nutrient pollution, specifically pertaining to phosphorus, we propose a method for using zero-valent iron (ZVI) to remove phosphorus from multiple water sources, including stormwater.

ZVI has been used for many treatment applications, and shown to remove a wide variety of chemical contaminants, including metallic ions (Al, Cu, Pb, etc.), halogenated hydrocarbons, and nitroaromatics (U.S. EPA, 2016), as well as biological contaminants, like viruses (You et al., 2005). Previously, ZVI has been shown to bind phosphate, either through adsorption or precipitation at the iron surface (Saxe et al., 2006). It was also reported that continuous iron-

supported phosphate removal could be sustained for one year (Erickson et al., 2012), as well as remove large amounts of phosphate (Allred, 2012).

1.2 Field Application

The use of ZVI for stormwater treatment would be a potential application, and it would be amended into a bioretention cell, as pictured in Figure 1. ZVI amendment would be in the anaerobic zone of the ground, thus preventing fast corrosion by both water and oxygen, as well as in the saturated zone, keeping the ZVI consistently exposed to water. The anaerobic corrosion products, mostly Fe^{2+} , as seen in Equation 1, are able to react with incoming phosphorus, as illustrated by Equation 2.

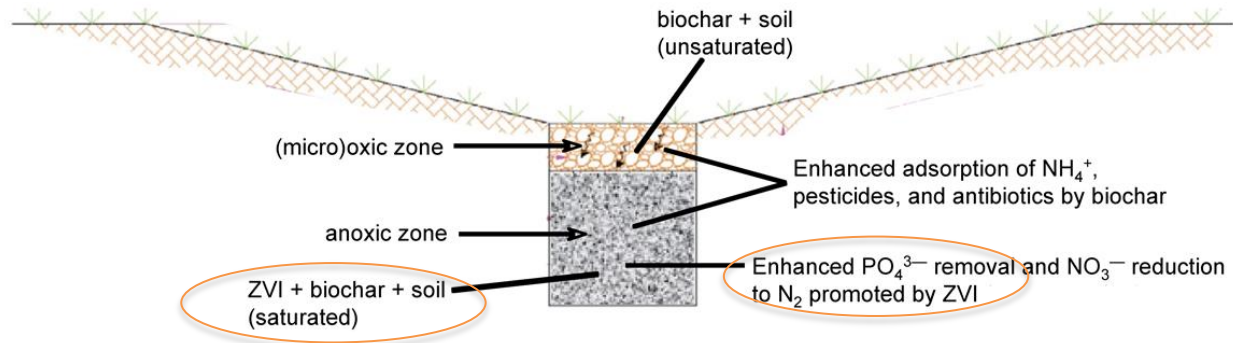
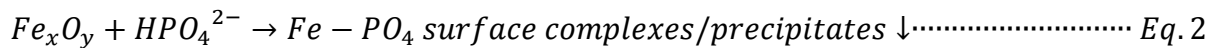
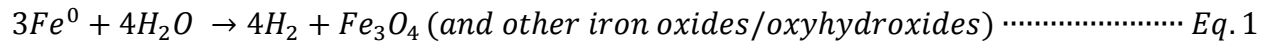


Figure 1. Schematic of a potential bioretention filter design for nutrient removal; areas highlighting ZVI addition and phosphorus removal are circled in orange.



1.3 Objectives:

1. To determine the removal efficiency of phosphate and the mass of phosphate removed using ZVI.
2. To construct a model, including terms to describe dispersion, retardation, and reaction, to confirm the observational data.
3. To determine the extractable fraction of phosphorus from our system.

2. Methodology

2.1 Media Preparation

Sand (Accusand 40/50, particle sizes in desired range of 250 to 500 micron) was treated with citrate to remove excess iron oxides (or manganese oxides, if present). This was done by submerging about 800 mL of dry sand in approximately 250 mL of 10 mM sodium citrate (enough to submerge the sand) and warm temperature ($\leq 40^{\circ}\text{C}$) for varying time lengths, usually left overnight. Sodium citrate (10 mM) was used as a complexing agent (Deng & Zhou, 2009), with higher temperatures were used to solubilize iron or manganese. 5-mL samples from the aqueous layer were taken and analyzed using the 1,10-phenanthroline method measured on UV-Vis at 510 nm for the amount of iron removed from the sand. These samples were analyzed in triplicate. The sand was then rinsed thoroughly with deionized water. This process was repeated for a total of four times to ensure that the iron oxides were removed from the sand. This was confirmed by a decreasing amount of iron removed during each wash.

Additionally, the sand was tested to ensure that little to no phosphorus would be removed by the sand alone. This was done by using 50 mL of the dried, treated sand in 100 mL of deionized water containing 1.69 ± 0.000123474 mg/L $\text{PO}_4\text{-P}$. The concentration of phosphorus in solution was tested after an hour, using phosphate/molybdate complex and ascorbic acid reduction; measured on UV-Vis at 880 nm (Hach PhosVer 3 reagent). The samples were analyzed in triplicate.

The ZVI used is in the form of scrap iron granules from Peerless Metal Powders and Abrasive, in Detroit MI, and sieved to the desired particle size range of 250 to 500 micron. The ZVI granules were used as is, not pretreated before being packed in columns.

2.2 Solution Preparation

The solutions used were composed of deionized water that was purged with nitrogen gas for 2 hours (per one liter), then degassed in a vacuum chamber for 20 minutes (up to -27 in. Hg). After degassing, the solution pH was adjusted to between 8.5 and 9.5 by using 6 N NaOH. This was used as the “blank” influent, as media to prepare other solutions, and to pack the columns (see “Media Preparation”).

For influent containing phosphorus, the blank solution was spiked with K_2HPO_4 (final concentration 1.6, 3.2, 8, or 16 mg/L $\text{PO}_4\text{-P}$). By using the high pH solution, this ensured that the species of phosphorus would be HPO_4^{2-} for the entirety of the experiment; the pKa's of phosphate species can be seen below, Equations 3 – 5 (Stumm and Morgan, 1996) and Figure 2. The high pH would also ensure that ZVI was corroded slowly.

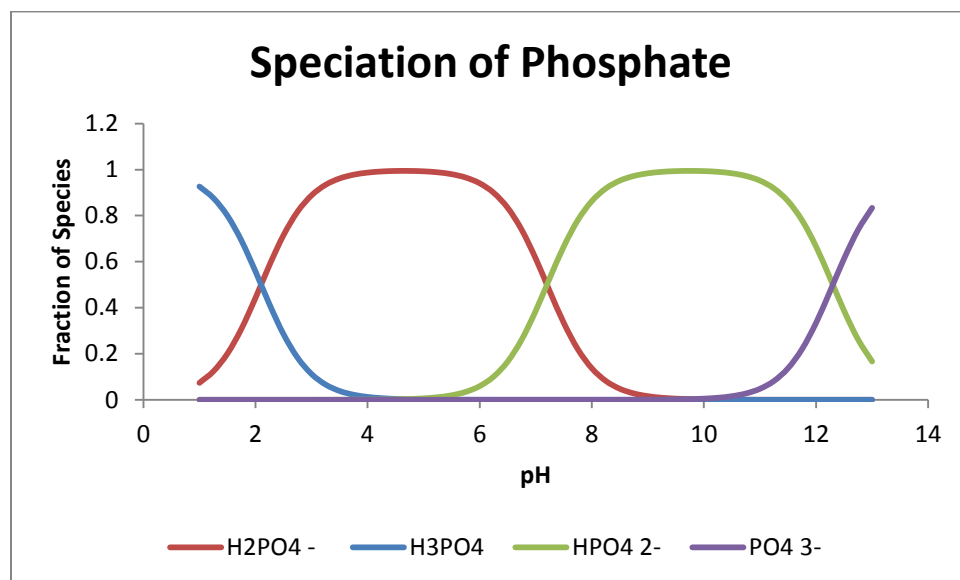
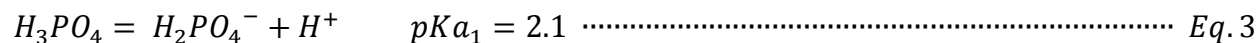


Figure 2. Speciation of phosphate versus pH. The species of interest, in this study, is HPO_4^{2-} , which is present in the highest fraction around pH 9, which is why this pH was chosen for the solutions.

The concentrations of PO_4 -P were chosen as dilutions, starting with 16 ppm – 8 ppm was a two-fold dilution, 3.2 was a five-fold dilution, and 1.6 was a ten-fold dilution. Although even the lowest concentration is still significantly higher than the concentration seen in the field [field concentrations can be greater than 0.4 ppm total phosphorus (Ator, S.W., and Denver, J.M., 2015)], it was chosen for two reasons: (1) we did not want our PO_4 concentration too close to the detection limit of our method, to ensure confidence in our data, and (2) in order to properly analyze our samples, which are 5 mL total, we need to have enough for pH measurement, PO_4 analysis, and tot Fe analysis. A concentration lower than 1.6 ppm PO_4 -P would require all (or more) of the 5 mL sample, leaving nothing left for the additional analyses.

2.3 Column Setups

The columns used were acrylic, with a total volume of 114.55 cm³ that were manufactured in the College of Engineering's Machine Shop. The dimensions are as follows: length, 10.1 cm; inside diameter, 3.8 cm. The columns are fitted with mesh screens to ensure that no media particles will be eluted from the column, and nylon barbed tube fittings on either side. These fittings are connected to Tygon Tubing (L/S 16, with inside diameter 3.1 mm). Since the columns are up-flow, the influent enters the bottom of the tubing, from a 1-L influent reservoir, and out of the top of the columns. The solution is pumped through the columns using a peristaltic pump.

The columns were wet-packed using the blank influent solution (high pH, degassed DI water) to avoid air bubble formation in the column. The control column was packed with sand only, using the citrate-treated sand. The experimental column was packed in three layers: the first 2 cm was citrate-treated sand, the middle 6.1 cm was a mixture of 5% ZVI/95% Sand, by volume (7.3% ZVI/92.7% citrate-treated sand by mass), and the final 2 cm was citrate-treated sand. The end sand layers act to even the flow before reaching the reactive center of the column.

The pump was calibrated, and set at 1 mL/min (measured flow rate) for the duration of the experiments.

The column experimental setups can be seen below in Figure 3.

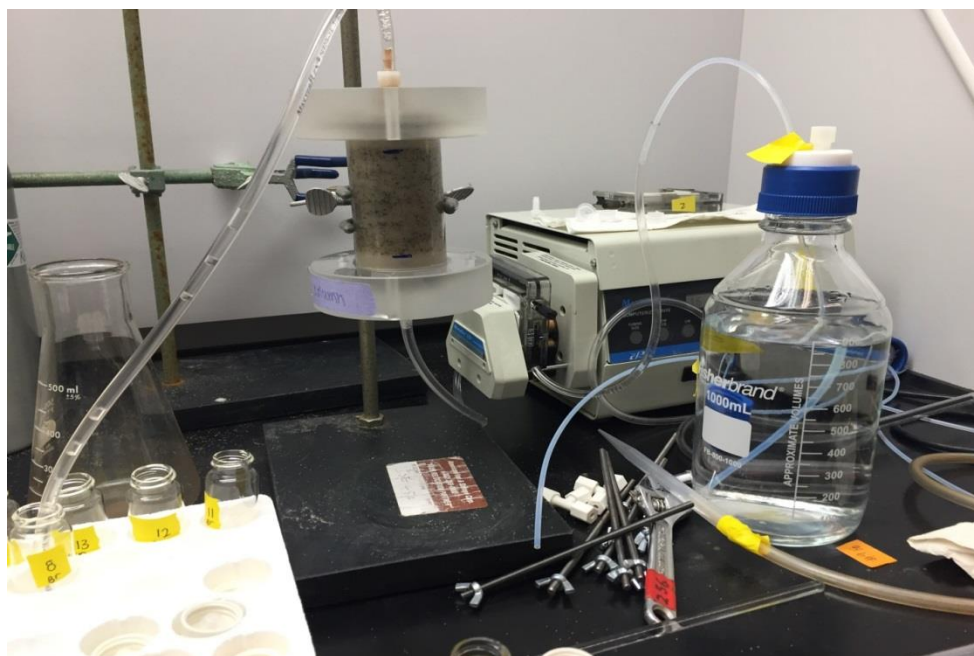


Figure 3. Experimental (ZVI) column set up; control (sand only) column setup is the same.

2.4 Column Experiments

Once assembled, the columns were flushed with blank influent for three pore volumes. After the initial flush, the influent was switched to the solution containing phosphorus, and sample collection began. A pulse of one pore volume of influent solution (containing P) was conducted before switching the influent back to the blank solution for the remainder of sample collection.

For the control column, samples were collected for the first 40 minutes every 10 minutes (each sample, ~10 mL). From 40 to 110 minutes, samples were collected every 5 minutes (each sample, ~5 mL). For the remainder of the time, up to 170 minutes, samples were collected every 10 minutes. During the pulse test, pH was monitored periodically, and PO₄-P analysis was performed on every sample. For PO₄-P analysis, samples were diluted accordingly to get a measurable concentration, and analyzed using UV-Vis at 880 nm (Hach PhosVer 3 reagent). The phosphorus pulse test was repeated four times in total, one for each of the concentrations of phosphorus (1.6, 3.2, 8, and 16 mg/L PO₄-P).

For the experimental column, the process for sampling was similar, with the addition of total iron analysis periodically during pulse test. Total iron was analyzed for using the 1,10-phenanthroline method measured on UV-Vis at 510 nm. The first pulse test was the lowest concentration of phosphorus (1.6 ppm PO₄-P). There was an additional pulse test performed using this ZVI column, to determine the approximate breakthrough time of phosphate. To do this, the influent solution contained 16 ppm PO₄-P (ten times higher than the previous concentration) was introduced to the column for one pore volume. After one pore volume, the solution was switched back to the blank influent. Samples were collected every 15 mins (~15 mL) for 8 pore volumes total.

Second and third ZVI columns were set up following the conclusion of the 16 mg/L PO₄-P pulse test, one for the 3.2 mg/L PO₄-P pulse and the other for the 8 mg/L PO₄-P pulse. Sampling for both columns followed the same procedure as the sand columns..

2.5 Data Analysis and Modeling

To model the observed effluent concentrations, the 1D Advection-Dispersion-Reaction Equation, with first order rate kinetics was used:

$$D \frac{\partial^2 C}{\partial x^2} - v \frac{\partial C}{\partial x} - \lambda C = \frac{\partial C}{\partial t} \dots\dots\dots \text{Eq. 6}$$

Where λ is the rate constant, with units time^{-1} ; v is the velocity, with units length time^{-1} ; and D is the dispersion coefficient, with units $\text{length}^2 \text{time}^{-1}$. The first term in the equation describes the mass transport by diffusion, the second term describes the mass transport by advection, and the third term describes the first-order reaction (Domenico and Schwartz, 1998).

The analytical solution for Equation 6 (Wexler – USGS, 1992) is given as follows, Equations 7-10:

$$C(x, t) = \frac{C_o}{2} \left\{ \exp \left[\frac{x}{2D} (v - U) \right] \cdot \text{erfc} \left[\frac{x - Ut}{2\sqrt{Dt}} \right] + \exp \left[\frac{x}{2D} (v + U) \right] \cdot \text{erfc} \left[\frac{x + Ut}{2\sqrt{Dt}} \right] \right\}, \dots\dots \text{Eq. 7}$$

$$U = \sqrt{v^2 + 4\lambda D} \dots\dots\dots \text{Eq. 8}$$

$$v = \frac{\text{velocity of water in column}}{R_f} \dots\dots\dots \text{Eq. 9}$$

Where C_o is the initial influent concentration, with units mass volume^{-1} ; x is the length of the column; erfc is the complementary error function; and R_f is the retardation factor.

For a conservative tracer ($\lambda = 0$), as in the case of the sand only column, the solution condenses to:

$$C(x, t) = \frac{C_o}{2} \left\{ \operatorname{erfc} \left[\frac{x - vt}{2\sqrt{Dt}} \right] + \exp \left[\frac{xV}{D} \right] \cdot \operatorname{erfc} \left[\frac{x + vt}{2\sqrt{Dt}} \right] \right\}, \dots \text{Eq. 10}$$

Since the conditions in the experiments were pulse tests, Equation 10 applies during the phosphorus-containing influent pulse, when $0 < t \leq 45$ minutes. After the pulse, the influent is switched back to anaerobic, DI water, and the “t” in the analytical solution becomes $t - 45$ minutes; the entire set of equations as follows:

$$C(x, t) = \begin{pmatrix} \frac{C_o}{2} A(x, t) & \text{for } 0 < t \leq 45 \\ \frac{C_o}{2} [A(x, t) - A(x, t - 45)] & \text{for } t > 45 \end{pmatrix} \dots \text{Eq. 11}$$

$$A_{ZVI}(x, t) = \left\{ \exp \left[\frac{x}{2D} (v - U) \right] \cdot \operatorname{erfc} \left[\frac{x - Ut}{2\sqrt{Dt}} \right] + \exp \left[\frac{x}{2D} (v + U) \right] \cdot \operatorname{erfc} \left[\frac{x + Ut}{2\sqrt{Dt}} \right] \right\}, \dots \text{Eq. 12}$$

$$\begin{aligned} A_{ZVI}(x, t - 45) \\ = \left\{ \exp \left[\frac{x}{2D} (v - U) \right] \cdot \operatorname{erfc} \left[\frac{x - U(t - 45)}{2\sqrt{D(t - 45)}} \right] + \exp \left[\frac{x}{2D} (v + U) \right] \right. \\ \left. \cdot \operatorname{erfc} \left[\frac{x + U(t - 45)}{2\sqrt{D(t - 45)}} \right] \right\} \dots \text{Eq. 13} \end{aligned}$$

$$A_{sand}(x, t) = \operatorname{erfc} \left[\frac{x - vt}{2\sqrt{Dt}} \right] + \exp \left[\frac{xV}{D} \right] \cdot \operatorname{erfc} \left[\frac{x + vt}{2\sqrt{Dt}} \right], \dots \text{Eq. 14}$$

$$\begin{aligned} A_{sand}(x, t - 45) \\ = \operatorname{erfc} \left[\frac{x - v(t - 45)}{2\sqrt{D(t - 45)}} \right] + \exp \left[\frac{xV}{D} \right] \cdot \operatorname{erfc} \left[\frac{x + v(t - 45)}{2\sqrt{D(t - 45)}} \right] \dots \text{Eq. 15} \end{aligned}$$

In order to confirm the observed effluent concentrations from the sand column, two parameters (R_f and D) were fitted using solver to minimize the sum of the residuals squared (RMSE). For the ZVI column, the same two parameters were fitted first, with $\lambda = 0$, and C_o as a percent of influent concentration, determined by dividing the highest effluent concentration by the influent concentration. This percentage was modified until the smallest RMSE was obtained. Once the optimal R_f and D parameters were obtained, the C_o fraction was set to 1 (100% of the influent concentration), and solver was used to fit λ .

3. Results and Discussion

3.1 Control Column (Sand Only)

Graphical results for the four concentrations of phosphorus (1.6, 3.3, 8, and 16 ppm PO₄-P) are presented in Figure 4. As seen in the effluent concentration of the column, the pulse of phosphorus-containing solution comes out later than expected; a pulse of contaminant for one pore volume is expected to elute from a column starting at one pore volume of collected effluent, and end at two pore volumes. Our pulse is shifted to the right, so this indicates some retardation by the sand on the phosphorus solution. Additionally, since the effluent pulse is not in the shape of a rectangle, as seen in the influent pulse, there is some dispersion in the column. Using the model as described earlier, the dispersion coefficient and retardation factor were calculated to confirm the observational data. These fitted parameters are summarized in Table 1a. Furthermore, since phosphorus can be considered a “conservative tracer”, that is, it is not retained in the column, and should be eluted completely, we would expect a percent recovery of about 100%. The percent removals are shown in Table 1a.

Upon comparing the dispersion coefficients for the four different influent concentrations, it can be seen that they are quite similar; this is because the four concentration pulses were performed using the same column. The same observation can be made for the retardation factors. The retardation of the phosphorus pulse could be due to the surface charge of the sand, but this doesn't affect the discharge of the entire pulse from the column.

Furthermore, our assumption of phosphorus as a conservative tracer was confirmed by having percent recoveries of over 99.9% for each concentration. This proves to be a good control column, since nearly all of the influent phosphorus is recovered, and there is no reaction between sand and phosphorus.

3.2 Experimental Column (ZVI + Sand)

Graphical results for the four concentrations of phosphorus (1.6, 3.3, 8, and 16 ppm PO₄-P) are presented in Figure 5. Similar observations as the sand experiments can be made about these data sets: the pulse of phosphorus-containing solution comes out later than expected, proving that a retardation factor is needed; and, the pulse is not in the same of a rectangle, as in the influent pulse, needing a dispersion coefficient for the system. Also, it can be seen that the pulse height is lower than the influent height for all four concentrations, confirming that a reaction with the ZVI was occurring, and the need for a reaction term in the model equation. The three fitted parameters for the ZVI experiments are summarized in Table 1b, along with the percent recoveries. Note that in Figure 3a (1.6 ppm), there is no breakthrough curve, and thus, a model could not be constructed for this data.

Additionally, the total iron concentration was measured periodically during each pulse test. The highest concentration observed was 0.56 ppm of total iron. This low concentration does not

interfere with phosphorus analysis, and does not contribute any color (rust) to the effluent solution.

Comparing the dispersion coefficients for the four different influent concentrations, it can be seen that they are again, similar, like the sand columns. However, when comparing the retardation factors and reaction coefficients for each concentration, the trend is with increasing concentration, the retardation and reaction coefficients both decrease. This is likely due to the increase in concentration of phosphorus overwhelming the system.

There is no obvious trend between the influent concentration and percent removal for all four runs, and this is likely due to using different columns for some concentrations, and not for others. However, we can say that the phosphate removal is most likely associated with the corrosion products. Since the corrosion of ZVI is continuous over time, and the 16 ppm PO₄-P pulse test was performed on an aged column and resulted in good removal, this suggest the corrosion products are responsible for the retention of phosphorus.

It is also important to again note the importance of the concentrations used. The most significant concentration for field application is 1.6 ppm PO₄-P, since the field concentration is typically around 0.4 ppm PO₄-P. Since almost all of the phosphorus was retained in the column at 1.6 ppm, at field concentrations, we would also expect all of the incoming phosphorus to be retained.

Control Column Model Parameters				
Influent Concentration <i>mg/L</i>	Dispersion Coefficient <i>cm^2/min</i>	Retardation Factor	Percent Removal %	
1.6	2.15E-02	1.459	0.004	
3.3	2.15E-02	1.459	0.01	
8	2.15E-02	1.416	0.03	
16	1.76E-02	1.352	0.05	
Experimental Column Model Parameters				
Influent Concentration <i>mg/L</i>	Dispersion Coefficient <i>cm^2/min</i>	Retardation Factor	Rate Constant <i>1/min</i>	Percent Removal %
1.6	-	-	-	~100
3.2	1.32E-02	2.014	1.33E-02	69.93
8	1.15E-02	1.700	4.15E-03	27.46
16	1.77E-02	1.475	6.77E-03	36.34

Table 1. (a) Summary of fitted model parameters [using equations (14) and (15)] for control (sand only) column, at different influent concentrations of PO₄-P; (b) Summary of fitted model parameters [using equations (12) and (13)] for experimental (7.33% ZVI/92.7% sand, by volume) column, at different influent concentrations of PO₄-P. Note: There are no parameters included for the lowest concentration of phosphorus in the experimental column because no breakthrough curve was observed (~100% removal).

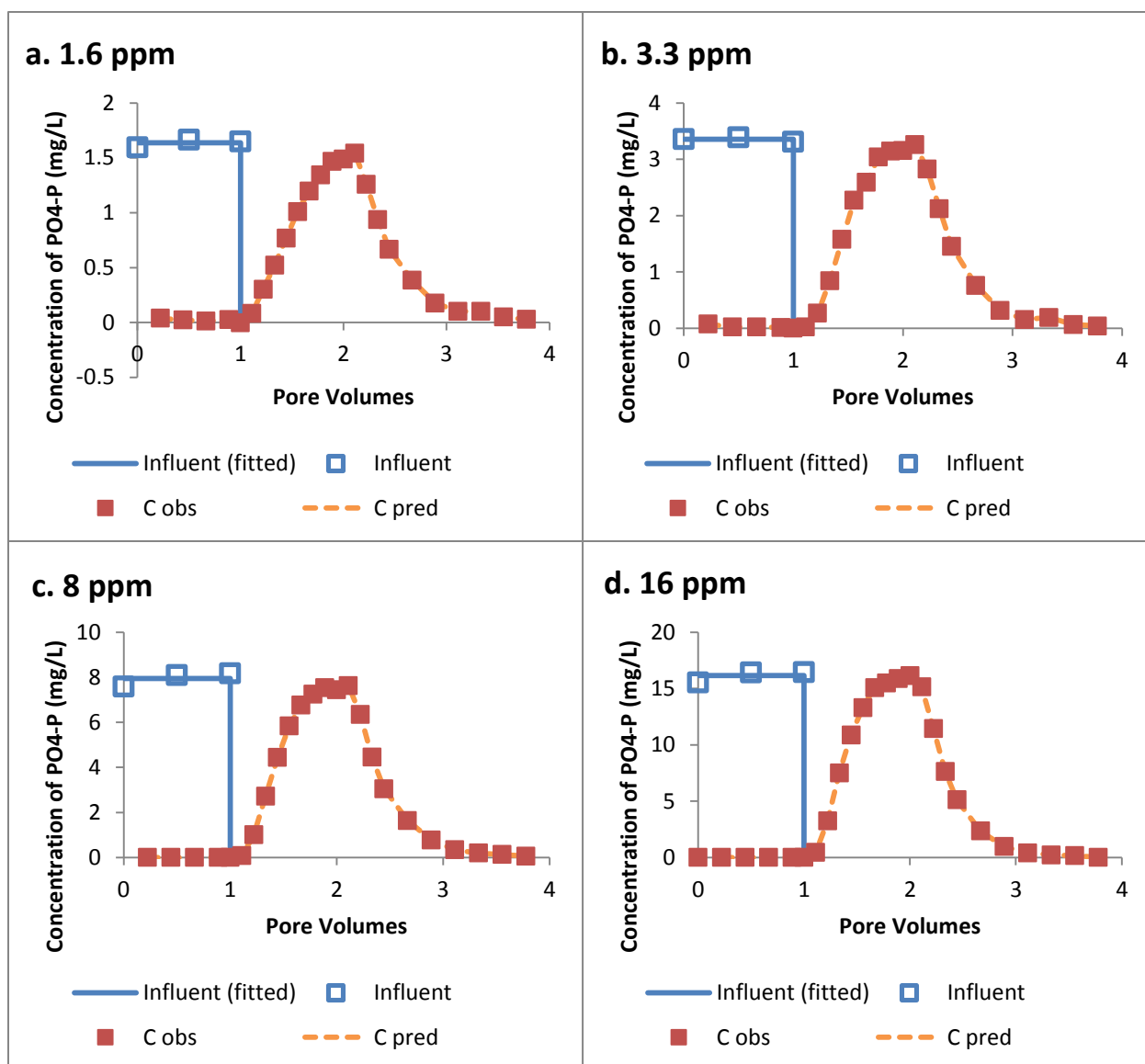


Figure 4. All data from control (sand only) column for 4 different concentrations: (a) 1.6 ppm PO₄-P, (b) 3.3 ppm PO₄-P, (c) 8 ppm PO₄-P, and (d) 16 ppm PO₄-P.

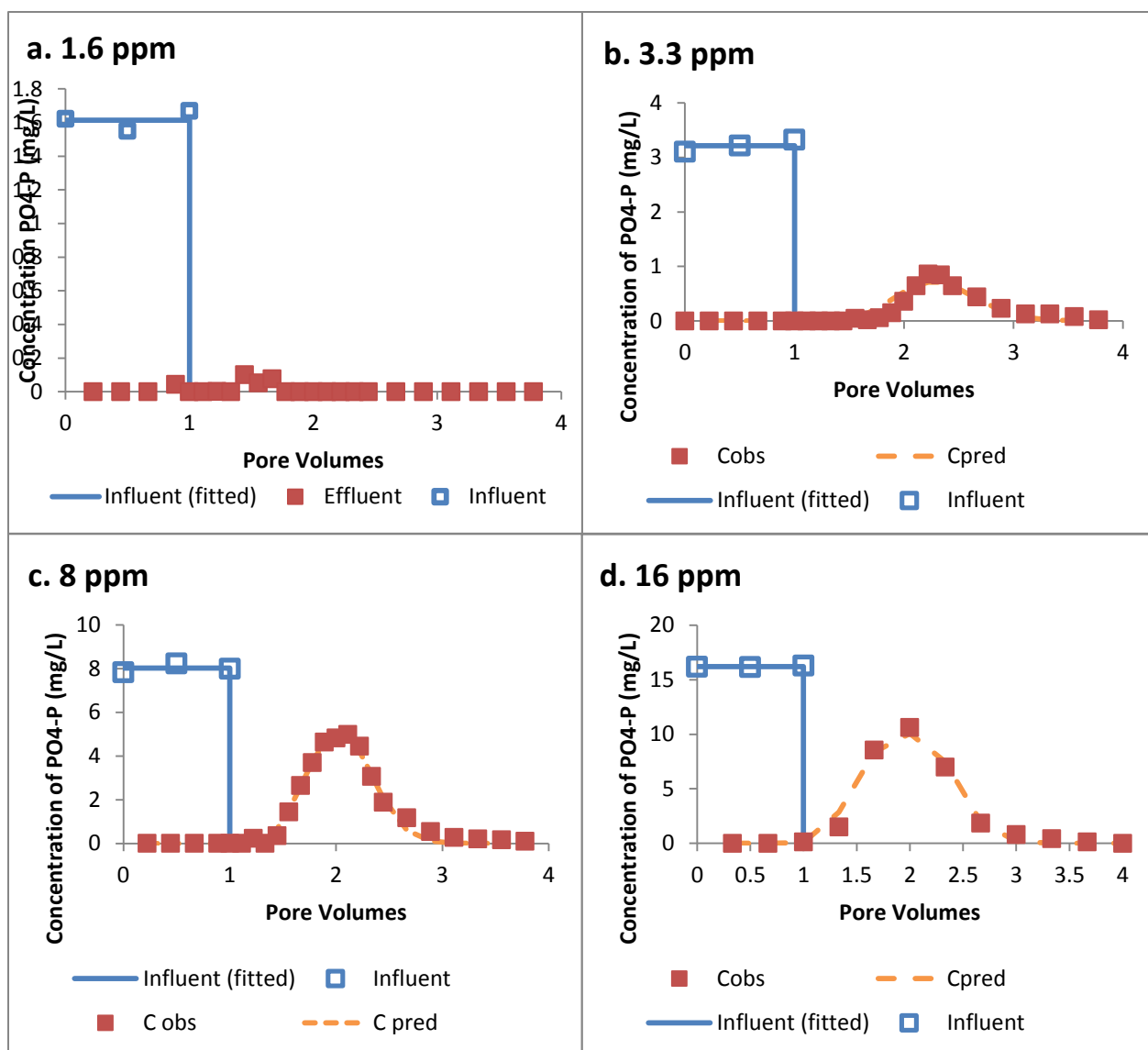


Figure 5. All data from experimental (5% ZVI by volume/95% sand) column for 4 different concentrations: (a) 1.6 ppm PO₄-P, (b) 3.3 ppm PO₄-P, (c) 8 ppm PO₄-P, and (d) 16 ppm PO₄-P.

Conclusions and Further Work

These column studies showed how the use of ZVI can affect phosphate removal from stormwater, which has field applicability in a bioretention cell. We were able to report the removal efficiencies of ZVI amendment, by modeling the flow of phosphorus through columns using the advection-dispersion-reaction equation, which confirms the observational data well. Furthermore, it was shown that even at high concentrations of phosphorus, likely never seen in the field, ZVI was capable of removing more than 30% of influent phosphorus. At field concentrations, of approximately 0.4 ppm total P, we would expect ~100% removal, as seen in our lowest concentration (1.6 ppm PO₄-P).

Continuing this research, we will expand to determine the fraction of extractable phosphorus from sections of our columns. We are planning three sets of extractions to determine loosely-bound phosphorus, surface complexed phosphorus, and acid-extractable phosphorus. This will ultimately show the longevity of ZVI in terms of leaching any previously bound phosphorus.

We will also perform parallel column experiments using synthetic stormwater instead of deionized water, under the same pH and phosphorus concentrations used in the above work.

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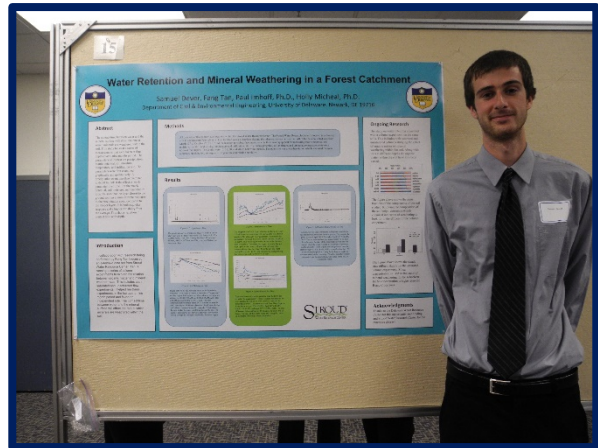
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Undergraduate Internship #1 of 15 for FY15

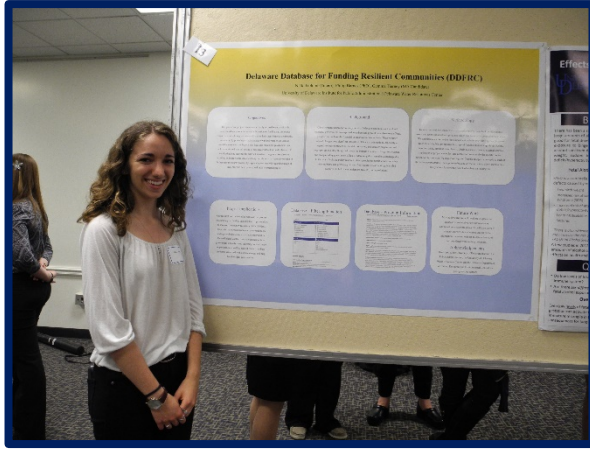
Intern *Samuel Dever* was sponsored by the *DWRC*. His final poster was titled “Water Retention and Mineral Weathering in a Forest Catchment.” He was advised by Dr. Paul Imhoff of the *UD*’s Department of Civil and Environmental Engineering.

Abstract

The contact time between water and the mineral surface will affect the rate at which minerals are weathered within the soil. This study looks at a series of measurements that were taken at four depths over a nine-month period. The parameters of interest are precipitation, matric potential, soil moisture, temperature, and infiltration rate. The parameters were first examined graphically and qualitatively. A precipitation event was then examined in detail to look at the effect on each parameter over time. For the matric potential, soil moisture, and temperature it can be seen that the layer closest to the ground soil has a more extreme response to the precipitation event compared to the deeper layers. It is both a quicker response and a higher variability from the average. This shows variation in contact time with depth.



Undergraduate Internship #2 of 15 for FY15



Intern *Nicole Golomb* was sponsored by the *DWRC*. Her final poster was titled “Delaware Database for Funding Resilient Communities (DDFRC).” She was advised by Philip Barnes of the *UD*’s Institute for Public Administration.

Abstract

The goal of our project is to create an easily accessible and navigable database which houses important information on funding and assistance resources available to government officials to help them improve community resiliency. By providing a

single database with information on various available resources, our hope is that local and municipal governments are able to locate and take advantage of resources without the added burden of conducting long searches for relevant assistance programs. Additionally, by creating an instructional video to teach users how to use the database and the filtering functions, we further reduce the amount of time government officials will spend searching for funding and assistance opportunities.

In order to meet our goal, we conducted an exhaustive internet search of possible grants, loans, and technical assistance programs which aim to increase community resiliency. We compiled all of the information into one document, which supplies information such as providing agency, program description, eligible project activities, typical funding amount, eligible applicants, important dates, information on how to obtain assistance, links to external sources, application or project examples, and contact information for the specific contact person for the program.

Our next major step in the project was determining how our filtering functions would work. We first decided what information would be the most important for users in choosing assistance programs. Then, based on these categories, we decided upon tags to use which help in filtering the resources based on the community’s specific needs. Once we completed the tagging process, we populated the database with the assistance programs and filtering functions. The final step of our research was to create the instructional video and publicize it, teaching users how to navigate the database and use the tagging system.

In this research project, I discovered that the information required to help government officials address community resiliency is available but not very well organized. Various agencies and national foundations have resources available, but they are difficult to find unless one checks each source independently. Because of the lack of existing policy research in this area, local and municipal governments face great challenges in improving community resiliency and decreasing the effects of climate change. Our project, however, directly addresses this issue by organizing all relevant information in one location and making the database adaptable as new opportunities arise.

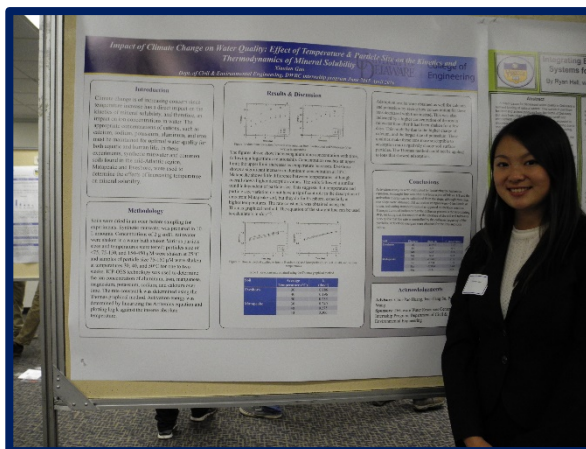
By compiling all of our findings in one database, we will significantly reduce the amount of time dedicated to searching for assistance programs. Because our data are specifically for Delaware local and municipal governments, they will only have to look through programs that apply to their area and not worry about opportunities outside of the region. By organizing all of this information in one location, we will effectively ease the process of searching for grants and assistance. The instructional video will also assist users in using the database quickly and efficiently. As such, the implications of our project will ultimately increase community resiliency and make it easier for government officials to reduce the effects of global climate change.

Undergraduate Internship #3 of 15 for FY15

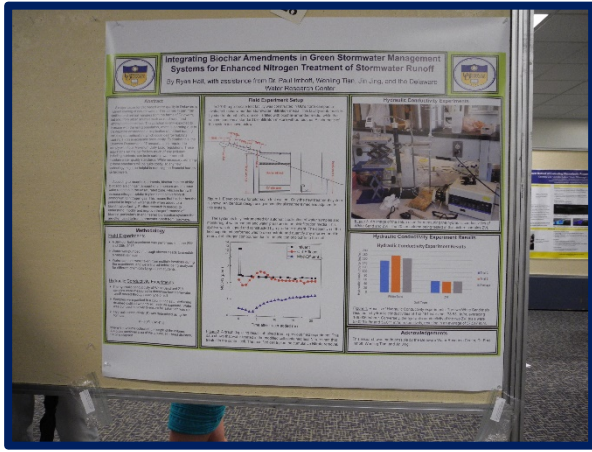
Intern **Xiaolun Guo** was sponsored by the **DWRC**. Her final poster was titled “Impact of Climate Change on Water Quality: Effect of Temperature and Particle Size on the Kinetics and Thermodynamics of Mineral Solubility.” She was advised by Dr. Chin-Pao Huang of the **UD’s** Department of Civil and Environmental Engineering.

Abstract

Climate change is of increasing concern since temperature increase is a major factor in chemical and biological processes, specifically in kinetics. The kinetics of mineral solubility have a direct impact on ion concentrations in water, which in turn affect the water quality. The appropriate concentrations of cations, such as calcium, sodium, potassium, aluminum, and iron must be maintained for optimal water quality for both aquatic and human life. In these experiments, synthetic rainwater and common soils found in the mid-Atlantic region, Matapeake and Evesboro, were used to determine the effects of increasing temperature on mineral solubility. Various particle sizes and temperatures were tested. ICP-OES technology was used to determine the ion concentration with time of aluminum, iron, manganese, magnesium, potassium, sodium, and calcium. We found that with decreasing particle size, ion concentrations generally increased. We found similar results with increasing temperature. However, we also saw decreasing ion concentration with time, leading us to conclude some ions were adsorbing onto soil surface particles. From desorption results only, we were able to find a rate constant k and an activation energy E_a , using both the Thomas graphical method and the Arrhenius equation. From this information, we were able to determine the rate-limiting step for the dissolution process of both soils into rainwater.



Undergraduate Internship #4 of 15 for FY15



Intern *Ryan Hall's* project, sponsored by the *DWRC*, was titled "Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nitrogen Treatment of Stormwater Runoff." He was advised by Dr. Paul Imhoff of the *UD's* Department of Civil and Environmental Engineering.

Abstract

A major cause for decreased water quality in Delaware is nutrient loading of natural waters, due to not only fertilizer and manures but also urban sources such as

road runoff. With rising population, this pollution is only expected to increase. To combat this, the Delaware Department of Transportation is required to comply with Total Maximum Daily Load regulations. While necessary, adhering to these standards is quite costly, so any new technology might be helpful in reducing the financial burden on taxpayers.

A recent solution to runoff pollution has been the implementation of bioretention areas. These are good at removing suspended solids, oil, grease, bacteria, heavy metals, and other nutrients, but not nitrogen. However, recent experiments show biochar can absorb a significant amount of ammonium and increase water retention in the unsaturated zone, which in turn will increase nitrogen uptake in plants and conversion of ammonium to nitrogen gas.

This past summer, laboratory and field experiments were performed to observe the effects of the amendment of biochar and zero-valent iron (ZVI). In the lab, column experiments were executed to measure the hydraulic conductivities of white sand and ZVI samples. Dried samples were packed into 20-inch long columns and saturated using de-aired distilled water. The head difference was measured by comparing water levels in tubes attached to the top and bottom of the column, the effluent volume was recorded with a small graduated cylinder, and the time elapsed was logged using a stopwatch. After numerous trials at different pump rates, the hydraulic conductivities were calculated using the following formula $K = [(V * L) / (A * H * t)]$. The white sand trials resulted in an average hydraulic conductivity of 166.006 inch/hour, while the average hydraulic conductivity of ZVI was 57.517 inch/hour, almost three times lower than that of white sand. These data show that ZVI would have better water retention than white sand, supporting the use of ZVI in bioretention media in order to reduce the effluent flow of stormwater runoff.

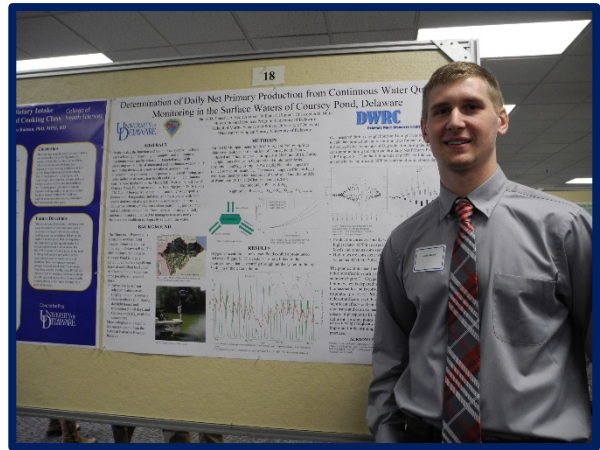
Additionally, a 36-hour field experiment took place on the University of Delaware's Laird Campus, where the effects of biochar-amended media on stormwater runoff were tested using a representative artificial rainfall event. A pilot-scale test facility had been constructed in 2014 containing side-by-side treatment cells, with one cell filled with biochar-amended media and the second containing a standard bioinfiltration mixture without biochar. During the experiment, water was pumped at equal rates through showerheads above each cell. Water samples were taken from multiple locations in the cells during the experiment, and were filtered before being analyzed for different chemicals by graduate students. After examination, it was seen that the amendment of biochar and zero-valent iron increased the residence time by 10%, and nitrate removal was amplified by 300%. While further research is needed, it appears that biochar and ZVI are promising solutions to increase both nitrate removal and retention time of stormwater runoff. If added to bioretention sites along roadways, biochar and ZVI should help unload runoff of its artificial nutrients, and in turn improve the quality of surrounding water.

Undergraduate Internship #5 of 15 for FY15

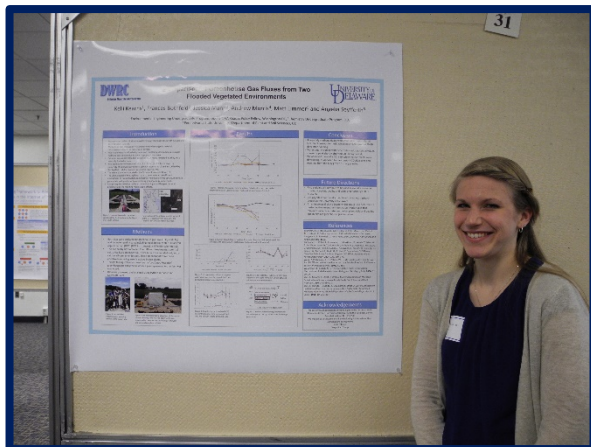
Intern **James Hanes** was sponsored by the **DWRC**. His final poster was titled “Determination of Daily Net Primary Production from Continuous Water Quality Monitoring in the Surface Waters of Coursey Pond, Delaware.” He was advised by Mr. A. Scott Andres of the Delaware Geological Survey.

Abstract

Traditionally, the function and health of ecosystems has been assessed using infrequent “grab samples” and minimum or maximum water quality criteria for targeted uses. With increasing availability of automated and continuous water-quality monitoring devices, it is now possible to assess rates of biogeochemical processes and responses to physical forcing, as a better indicator of ecosystem health and function. Continuous sensors were deployed on the Murderkill River at the outflow of Coursey Pond, Delaware to monitor Total Maximum Daily Loads (TMDLs) of bioreactive contaminants and other water quality parameters. Temperature and dissolved O₂, together with wind speeds determined at a nearby station, were used to determine daily gross primary production and respiration, O₂ gas exchange, and net primary production. These calculations are potentially automatable and can be used by managers to assess ecosystem behavior and health on ecologically relevant time scales.



Undergraduate Internship #6 of 15 for FY15



Intern **Kelli Kearns** was sponsored by the **DWRC**. Her final poster was titled “Comparison of Greenhouse Gas Fluxes from Two Flooded, Vegetated Environments.” She was advised by Angelia Seyfferth of the **UD’s** Department of Plant and Soil Sciences.

Abstract

This project compared two different flooded, vegetated systems for their greenhouse gas contributions during a seasonal timeframe, and was analyzed with water data such as redox potential, iron (II) concentration, and dissolved organic carbon concentration, in order to gain a better understanding of biogeochemical processes occurring within these flooded areas and their contributions to macroscopic greenhouse gas emissions. One of the sites is a protected estuary located in Dover, DE, and the other site includes a rice paddy cultivation plot located on the University of Delaware agricultural campus, constructed in order to represent global rice cultivation practices. The sites are similar because they are both flooded systems with high-silica-containing plants, but the estuary site is a naturally occurring system while the rice paddies are constructed to maintain flooding. An ultimate goal of the Seyfferth lab group is to determine a cost-efficient modification to rice cultivation soils that will minimize arsenic uptake, maximize rice plant quality and rice yield while minimizing greenhouse gas emissions that can result from the addition of an organic amendment. Four different treatments were considered: a rice husk-amended treatment, a rice husk ash-amended treatment, a calcium silicate-amended treatment, and a control soil without an amendment. The husk-amended soil showed a consistent peak in methane flux after about 20 to 30 days of sampling, while the other three treatments and the estuary grass site were relatively unchanging with time. Water data collected for the rice paddy cultivation soils during the same time period also showed a shift after 20 to 30 days, noticeable with all four treatments. In addition, carbon dioxide was noticed to gradually decrease with time for all four rice paddy treatments, and remained relatively constant with time for the estuary site. The results of this work will be used to compare with future data collection, and to allow researchers to gain a better understanding of the biogeochemical processes occurring in these two separate systems and their macroscopic effects on greenhouse gas production and consumption.

Undergraduate Internship #7 of 15 for FY15

Intern **Andres Kwart** was co-sponsored by the **DWRC** and the **UD's College of Agriculture and Natural Resources**. His final poster was titled "Development of a Fungal Biocell Reactor for Treatment of a Food Processing Wastewater." He was advised by Dr. Anastasia Chirnside of the **UD's** Department of Entomology and Wildlife Ecology.

Abstract

Currently, a soybean processing plant located in western Maryland has high concentrations of pollutants in its effluent wastewater. As a result, the facility managers have implemented a sophisticated treatment system consisting of an anaerobic lagoon, aeration basin, and two facultative lagoons. Still, effluent concentrations are too high. For example, the treated wastewater has a Total Kjeldahl Nitrogen (TKN) concentration that averages between 300 and 500 mg/L, a chemical oxygen demand (COD) concentration that averages between 4,000 and 5,000 mg/L, and a pH that is greater than 8. Despite high concentrations of wastewater pollutants, the processing plant still possesses a NPDES permit to discharge into surface waters. It has been argued that the high levels of complex nitrogen molecules in this wastewater are not an environmental concern because they are difficult for most nitrogen-degrading organisms to break down. Regardless, there is always a possibility that the complex nitrogen molecules get broken down into simpler compounds at some time and in some place. It is much safer to eliminate, or at least minimize, these harmful chemicals on the premises rather than take the risk of having them get naturally broken down and released to the environment. Therefore, the purpose of this study was to evaluate the ability of white rot fungi, grown on two types of support materials in a solid-state biocell reactor, to reduce high concentrations of TKN and COD in a food processing wastewater.

In order to address the purpose of this study, two growth support media were used: cornstalks, which are nutrient rich, and an inert support made of fibrous plastic. For each media, 6 reactors were used, 3 of which contained killed fungus and support materials. Once good growth was present, wastewater was pumped through all reactors and samples of each reactor, as well as the influent, were collected on days 0, 1, 2, 3, 4, 7, 10, 14, 21, 28, 35, 42, 49, and 56. For each sample, pH, COD, and TKN were measured, plotted, and analyzed.

The pH steadily increased between days 0 and 28. The greatest increase occurred between days 28 and 35, where pH increased by about 0.4 for all samples. After this increase, the pH remained relatively steady for the treatments and influent. In general, T1 and T3 (both with the inert support) had larger pH values than the influent. The pH of T4 was generally close to that of the influent, and the pH of T2 generally remained below that of the influent.

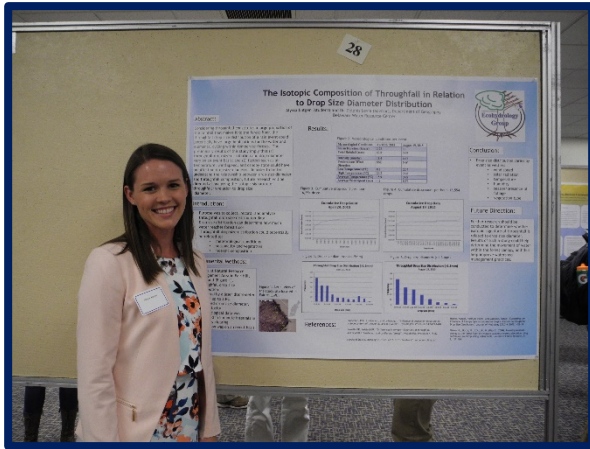
The COD of the influent increased by 1738.5 mg O₂/L over the 56-day testing period. The influent experienced the greatest increase in COD between days 21 and 28, where it increased by 1686 mg O₂/L. In general, T2 and T4 (lignocellulosic supports) had COD values larger than that of the influent. T1 and T3 generally had COD values smaller than that of the influent.



The TKN of all samples, including the influent, was generally between 100 and 200 mg/L. A few values lie outside of this range, but are most likely outliers as they do not follow the trend of the data. Generally, the TKN values for T2 and T4 were found to be greater than that of the influent. The TKN values for T1 and T3 were found to be less than that of the influent.

Overall, the inert support material did not increase the concentrations of TKN or COD in the effluent while increases were seen when the fungus was grown on the cornstalks. More work is needed to evaluate the influence of the inert support on the pH of the effluent and to develop better methods for inoculating the fungus on the inert support material.

Undergraduate Internship #8 of 15 for FY15



Intern *Alyssa Lutgen* was sponsored by the *DWRC*. Her final poster was titled “The Isotopic Composition of Throughfall in Relation to Drop Size Diameter Distribution.” She was advised by Dr. Delphis Levia of the *UD*’s Department of Geography.

Abstract

Considering throughfall constitutes a large proportion of the rainfall that makes it to the forest floor, the throughfall drop size distribution of a rain event could potentially have large implications for the water and elemental cycling within temperate forests. The preliminary results of this study imply that (1) throughfall drop size distribution and drop diameter vary on an event basis; and (2) factors such as air temperature, wind speed, and canopy state could have an effect on drop size diameter. In order to better understand the relationship between drop size diameter and throughfall composition, future research will be directed at analyzing the isotopic signature of throughfall in relation to drop size diameter.

Undergraduate Internship #9 of 15 for FY15

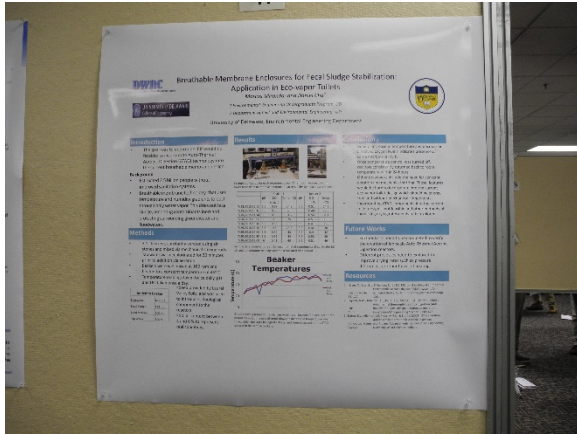
Intern **Jillian Matz** was sponsored by the **DWRC**. Her final poster was titled “Diel Patterns in Dissolved Organic Matter in a Forested Headwater Catchment in Maryland.” She was advised by Dr. Shreeram Inamdar of the **UD**’s Department of Plant and Soil Sciences.

Abstract

Patterns of water quality parameters such as dissolved organic carbon (DOC) and nitrate-N caused by biotic and abiotic processes in a watershed are important to understanding underlying biological and hydrological controls within a stream. This study investigates the nature of the short-term patterns of dissolved organic matter (DOM) that occur over a 24-hour period, and the potential variables that influence the concentration and composition of organic matter in a forested watershed. Closely analyzing these trends may allow us to predict how streams will respond to changing conditions, such as climate change.



Undergraduate Internship #10 of 15 for FY15



Intern **Marcos Miranda** was sponsored by the **DWRC**. His final poster was titled “Breathable Membrane Enclosures for Fecal Sludge Stabilization: Application in Eco-vapor Toilets.” He was advised by Daniel Cha of the **UD’s** Department of Civil and Environmental Engineering.

Abstract

The main focus of this research was to determine if components of an Auto-Thermal Aerobic Digestion (ATAD) system could be replicated on a laboratory scale. The next step would be to determine if these components could be incorporated into a current breathable membrane toilet design created by the late Dr. Steven Dentel. These toilets feature a breathable plastic membrane that has hydrophobic properties. These hydrophobic properties mean that while water molecules cannot pass through the membrane, the water vapor molecules can pass through the membrane due to even miniscule differences in temperature. Miniature reactors were created under laboratory conditions utilizing a synthetic sludge that was made in lab. This sludge was seeded with both compost and actual fecal matter to introduce microbes into the system in the hopes that they would increase temperature and subsequently the drying rate of the fecal matter. These reactors were well mixed using mechanical stirring rods and aerated through the use of air stones. Various measurements including pH, dissolved oxygen (DO), and temperature were taken daily to monitor the conditions within the reactor. The results indicated that it was feasible to generate small scale ATAD reactors using a laboratory system setup. Temperature levels were initially held constant but did show a slight increase after a period of time. Additionally, DO levels in each reactor dropped significantly throughout the experiment and there was a gradual increase in pH, indicating the presence of microbial activity within the reactors. With further consideration it was determined that the ATAD components may not be feasible to incorporate into the membrane toilet design. In order to be successful the ATAD system needs a constant heat, aeration, and mixing source. Each of these components would be difficult to incorporate into a cost efficient system that could be easily deployed and managed in a developing country to replace waterless pits. Additionally, the incorporation of these components would require an external energy source, another factor that makes incorporating these components difficult. Moving forward perhaps there is another method that can easily raise the temperature within the reactors to encourage evaporation of water vapor across the membrane.

Undergraduate Internship #11 of 15 for FY15

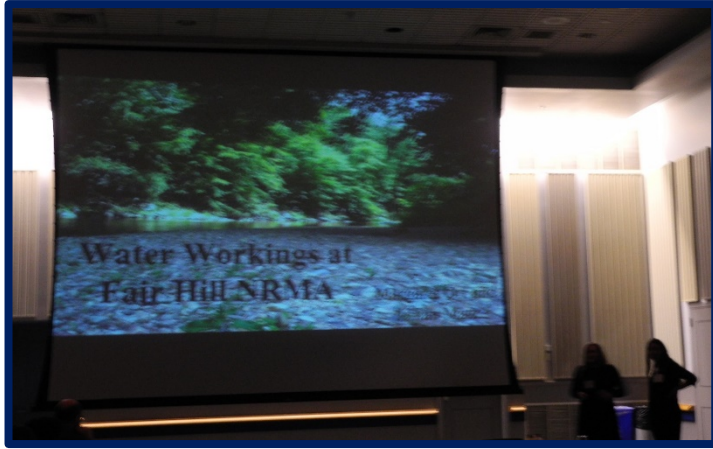
Intern *Adam Nesbitt* was sponsored by the **DWRC**. His final poster was titled “Potential for the Delaware Sustainable Energy Utility to Invest in Clean Water.” He was advised by Dr. Lawrence Agbemabiese of the **UD’s** Center for Energy and Environmental Policy.

Abstract

The State of Delaware has several water issues affecting current and future water security. Agricultural and industrial pollution has polluted the vast majority of Delaware’s water supply and the effects of global warming will only exacerbate these problems especially due to sea level rise along Delaware’s coast. I examined the major water issues facing the State of Delaware, assessed the State’s official goals for improving water security, and investigated whether the Delaware Sustainable Energy Utility can play a role in aiding the State to achieve its goals. I found that the Delaware Sustainable Energy Utility could begin collecting and making public information on the extent of Delaware’s water problems, which are not sufficiently researched, as well as investing in pollution reducing technology.



Undergraduate Internship #12 of 15 for FY15



Intern *Margaret Orr* was co-sponsored by the *DWRC* and the *UD's College of Agriculture and Natural Resources*. Her final poster was titled "Relating Rainfall Intensity to Sediment Mobilization at Fair Hill." She was advised by Shreeram Inamdar of the *UD's* Department of Plant and Soil Sciences.

Abstract

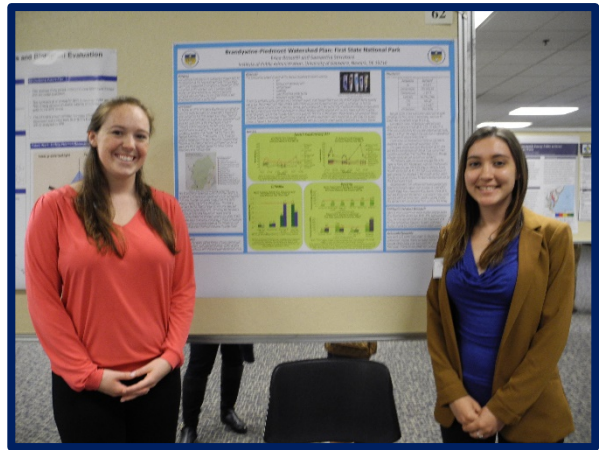
Precipitation has increased by about 5% in the United States over the past 50 years, with this increasing trend being most predominant in the Northeast. Among the effects of increased rainfall is increased sedimentation in streams. This study aimed to correlate increased rainfall with increased sediment mobilization in a small watershed located in the Fair Hill Natural Resource Management Area in Cecil County, Maryland. We used automated ISCO samplers to take water samples in response to rainfall, sediment concentration was calculated, and sediment was dried for further analysis. Hourly rainfall totals from DEOS (Delaware Environmental Observing System) data were compared to corresponding sediment values. Sediment concentrations were positively correlated with rainfall intensity.

Undergraduate Internship #13 of 15 for FY15

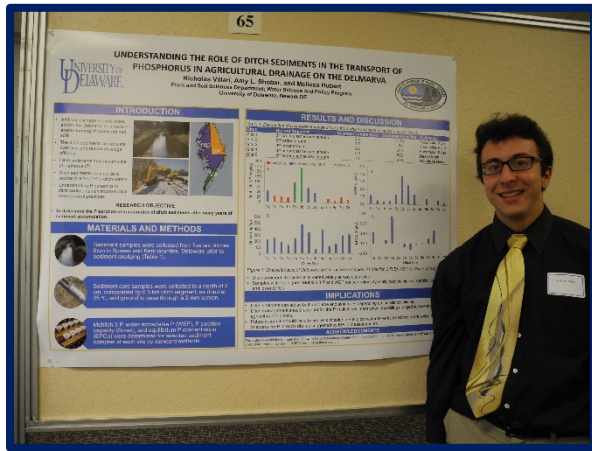
Interns *Samantha Serratore* and *Erica Rossetti* (pictured left to right) were sponsored by the *DWRC*. Their final poster was titled “Brandywine-Piedmont Watershed Plan: First State National Park.” They were advised by Dr. Gerald Kauffman of the *Delaware Water Resources Center*.

Abstract

Several chemical, nutrient, and biological indicators can help determine water quality and ecosystem health. As a newly designated national park, students at the University of Delaware found it important to monitor, record, and analyze several parameters including temperature, pH, conductivity, dissolved oxygen, turbidity, bacteria, nutrients, and metals to determine the general health of tributaries flowing through the Brandywine-Piedmont watershed in Delaware’s First State National Historic Park. Using probes and lab facilities from the City of Wilmington and the University of Delaware, data were gathered from twelve sites throughout the watershed several times over a period of nine months. Students analyzed data according to parameter, date, and statistical averages. When compared to standards, the results showed little to no nutrient and chemical impairments, but there were some indications of chemical and bacterial concern in sites adjacent to agricultural and commercialized areas, indicative of runoff pollution or other non-point sources. As a result of these conclusions, it is the researcher’s hope that the newly designated First State National Historic Park will act as a natural water quality improvement system or that the National Park Service will proceed with further investigations in order to prevent the degradation of the water quality in the watershed as indicated by this preliminary research.



Undergraduate Internship #14 of 15 for FY15



Intern *Nicholas Villari* was co-sponsored by the *DWRC* and the *UD's* Department of Plant and Soil Sciences. His final poster was titled "Understanding the Role of Ditch Sediments in the Transport of Phosphorus in Agricultural Drainage on the Delmarva." He was advised by Amy Shoher of the *UD's* Department of Plant and Soil Sciences.

Abstract

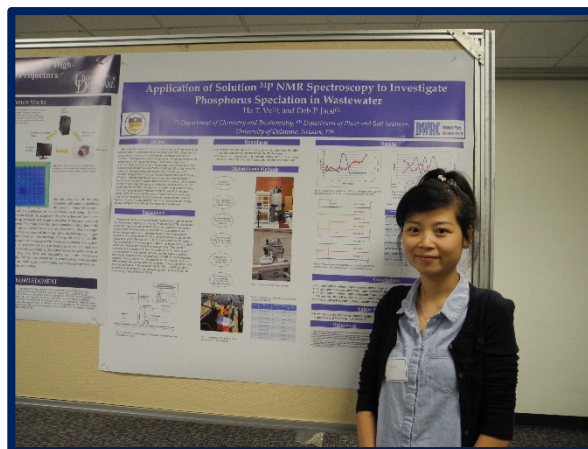
Nutrient pollution is a real concern on the Delmarva Peninsula due to the widespread presence of artificial drainage system across Delmarva and phosphorus (P) saturated soils. Accumulation of sediments in drainage ditches over time can affect nutrient transport because sediments may act as a source of P to the overlying water. However, ditch sediments may also act as a P sink, reducing the concentration of P in overlying ditch water. The objectives of this research were to determine the P sorption characteristics of ditch sediments after many years of sediment accumulation. Intact core samples were collected from the top 5-cm of sediment from five tax ditches in Delaware; sediment samples were analyzed for Mehlich 3 P and water extractable P (WEP). Sorption isotherms were also constructed to determine P sorption capacity (S_{\max}) and equilibrium P concentrations (EPCo) of collected sediments. The sediments collected from the drainage ditches actually had lower Mehlich 3 P and WEP concentrations than the agricultural fields they drained. The S_{\max} and EPCo of sediments ranged from 77.6 to 484 mg kg⁻¹ and -0.064 to 0.278 mg L⁻¹, respectively. Results suggest that ditch sediments are often acting as a sink for P, rather than a source. However, ditch water EPCo values need to be measured to confirm this finding.

Undergraduate Internship #15 of 15 for FY15

Intern **Ha Vu** was sponsored by the **DWRC**. Her final poster was titled “Application of Solution ^{31}P NMR Spectroscopy to Understand Phosphorus Speciation in Wastewater.” She was advised by Dr. Deb Jaisi of the **UD**’s Department of Plant and Soil Sciences.

Abstract

Microorganisms involved in the active P removal in the aeration basin in wastewater treatment plants (WWTP) undergo aerobic and anaerobic oscillations to facilitate denitrification. Microorganisms can uptake large amount of orthophosphate and transform this into polyphosphate (poly-P) and break poly-P down in an anaerobic stage to obtain energy. In this study, several samples were collected from the Kent County WWTP in Milford, Delaware, to determine the relationship between dissolved oxygen (DO) and changes in P speciation using solution P nuclear magnetic resonance spectroscopy (^{31}P NMR). Orthophosphate and pyrophosphate were the major P species in all samples. However, their dominance varied during aerobic condition; polyphosphate was much higher but decreased as the DO decreased. Furthermore, changes in monoesters and diesters during redox cycling suggested synthesis of both of these P compounds was slightly higher during the anaerobic cycle. These results provided clear insights into P speciation during redox alternation and are useful for tapping microbial incorporation of P into macromolecules and energy storage compounds for efficient P removal from wastewater.



Information Transfer Program Introduction

None.

DWRC Information Transfer

Basic Information

Title:	DWRC Information Transfer
Project Number:	2015DE275B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	DE-001
Research Category:	Not Applicable
Focus Category:	Water Quality, Water Supply, Education
Descriptors:	None
Principal Investigators:	Gerald Joseph Kauffman, Maria Pautler

Publications

There are no publications.

Information Transfer Program

The following section describes all Delaware Water Resources Center information transfer activities during FY15, consolidating reporting into a single project **#2015DE275B**. Most activities from the DWRC's FY14 Information Transfer project (**#2014DE257B**) continued into this year.

The FY15 DWRC Information Transfer Activities include:

- Delaware Water Resources Center Electronic Publication WATER NEWS (2000 – 2006 = print; 2007 – present = electronic)
- Delaware Water Resources Center Electronic Newsletter WATER E-NEWS (2002 – present)
- Delaware Water Resources Center Website (3rd edition launched in 2009)
- Delaware Water Resources Center E-group / Courses Link (2002 – present)
- Delaware Water Resources Center Intern Project Poster Session / Advisory Panel Annual Meeting (2001 – present)
- Delaware Statewide Conference Co-sponsor and Participant (2001 – present, when held)

Basic Information:**Delaware Water Resources Center Electronic Publication WATER NEWS**

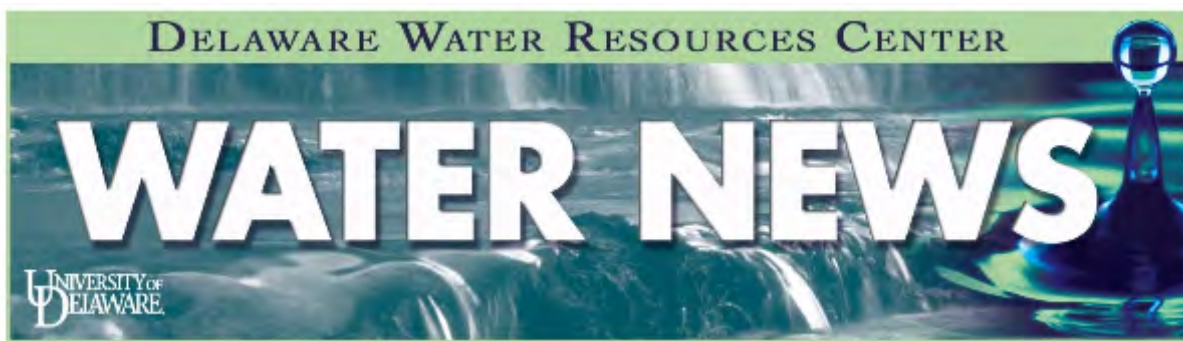
Title:	“WATER NEWS“
Issues during FY15:	Volume 14 Issues 3, 4
Description:	Online newsletter published periodically by the Delaware Water Resources Center
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Gerald Kauffman, Director; Maria Pautler, Editor

WATER NEWS is received electronically by over 300 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area as well as 100 nationwide contacts for water resource issues. It may be accessed via the Delaware Water Resources Center website at: <http://ag.udel.edu/dwrc/newsletters.html>.

Featured in each issue of WATER NEWS are:

- I. News items about the DWRC, including undergraduate internships and graduate fellowships
- II. Jobs in Water Resources
- III. Upcoming Water Conferences and Events
- IV. Water Resources Information and Training

[View this email in your browser](#)



August 2015

Volume 14

No. 3

Celebrating Our 50th Year!

[View the newsletter online](#)

Jerry Kauffman named Third Director of the DWRC

In January 2015, Dr. Jerry Kauffman was named the third Director of the Delaware Water Resources Center. Dr. Kauffman succeeds Dr. Tom Sims, Deputy Dean of the University of Delaware's College of Agriculture and Natural Resources who skillfully served as the second Director of the DWRC for a decade and a half and made a real and substantial difference in the careers and lives of many students, faculty, and staff who conducted research in water science and policy here at the University of Delaware.



Read Jerry's remarks [here](#)

DWRC Celebrates 50 Years!

The DWRC's 50th Anniversary was celebrated at the University of Delaware on April 17, 2015!

The DWRC is one of the 54 National Institutes for Water Resources (NIWR) funded by the U.S. Geological Survey at land grant universities in the 50 states, District of Columbia, and the three island territories of Guam, Puerto Rico, and US Virgin Islands. This year the DWRC celebrated our 50th anniversary of the center's designation at the University of Delaware in 1965, one year after Lyndon Baines Johnson signed the Water Resources Research Act (WRRRA) that established the NIWR program on July 17, 1964. The DWRC belongs to the mid-Atlantic NIWR region that includes our colleagues at Cornell, Penn State, Rutgers, Maryland, Virginia Tech, West Virginia and the University of District of Columbia.



At the annual April luncheon, DWRC Director, Jerry Kauffman, leads DWRC graduate and undergraduate students in a celebratory cake-cutting.

View a slide show [here](#)

View a celebratory video [here](#)

Read the UDaily article [here](#)

DWRC Advisory Panel

The DWRC Advisory Panel serves many essential functions, including peer review and ranking of research proposals, planning of annual conferences, promoting the interaction of the DWRC with other agencies, and advising the director on state priority water resource focal areas as well as the best ways to accomplish the center's mission.

The DWRC Advisory Panel is appointed by the Director for a three-year term and includes:

- Jayme Arthurs, USDA Natural Resources Conservation Service
- Chris Bason, Center for the Inland Bays
- Luc Claessens, Department of Geography
- Tom Coleman, City of Newark Water Department
- Jeff Downing, Mt. Cuba Center
- Asia Dowtin, UD student section of the American Water Resources Association
- Mingxin Guo, Department of Agriculture and Natural Resources, Delaware State University
- LeeAnn Haaf, Partnership for the Delaware Estuary
- Stephen Hokuf, New Castle County Department of Planning
- Paul Imhoff, Department of Civil and Environmental Engineering
- Shreeram Inamdar, Department of Plant and Soil Sciences

- Janet Johnson, Department of Political Science and International Relations
 - Richie Jones, The Nature Conservancy
 - Thomas McKenna, Delaware Geological Survey
 - Matt Miller, City of Wilmington Department of Public Works
 - Martha Narvaez, UD Water Resources Agency
 - Ginger North, Delaware Nature Society
 - Betzaida Reyes, U.S. Geological Survey
 - Kash Srinivasan, Kash LLC
 - Bob Struble, Brandywine Valley Association
 - Jennifer Volk, Kent County Cooperative Extension, Department of Plant and Soil Sciences
 - Jennifer Walls, Delaware DNREC, Division of Watershed Stewardship
-

DWRC Undergraduate and Graduate Internship Program

DWRC undergraduate and graduate internships are funded by Congress through the USGS to provide a unique opportunity for students and faculty to become directly involved in research and education programs that address water resource-related issues of critical importance to Delaware and the Mid-Atlantic region. Interns are from a variety of disciplines and programs throughout the University of Delaware campus. The 2014-2015 program included the following 12 undergraduate interns with faculty members and research topics:

Environmental Engineering major Katelyn Csatari

Advisor: Dr. Rodrigo Vargas, UD Department of Plant and Soil Sciences

Greenhouse Gas Emissions from Sediments in Floodplains of the Delaware Piedmont, Christina River Basin

Environmental Science major Sandra Demberger

Advisor: Dr. Luc Claessens, UD Department of Geography

Mushroom Farming and Its Effect on Nitrogen Loading in the Brandywine-Christina Watershed

Environmental Science major Amanda Doremus

Advisor: Dr. Carmine Balascio, UD Department of Plant and Soil Sciences

Water Quality Performance for Paired Bioretention Basins

Environmental Engineering major Jessica Fedetz

Advisor: Ms. Jennifer Volk, UD Department of Plant and Soil Sciences

Advisor: Ms. Marcia Fox, Delaware Dept. of Natural Resources and Environmental Control, Watershed Assessment Section

Quantifying Conservation Practices in the Chesapeake Bay Basin

Ecology and Marine Science double major Amelia Harrison

Advisor: Dr. K. Eric Wommack, UD Department of Plant and Soil Sciences

Fine-scale Temporal Dynamics of Estuarine Virioplankton and Bacterioplankton Populations

Mechanical Engineering major Sarah Hartman

Advisor: Dr. Steven Dentel, UD Department of Civil and Environmental Engineering

Enhanced Pollutant Biodegradation by Electrode Use

Environmental Science and Environmental Engineering double major Erica Loudermilk

Advisor: Dr. Angelia Seyfferth, UD Department of Plant and Soil Sciences

Understanding Greenhouse Gas Fluxes in Estuaries

Environmental Engineering major Danielle Notvest
Economics, and Environmental and Resource Economics double major Radhika Samant
Advisor: Dr. Gerald Kauffman, UD Water Resources Agency
Wetland Restoration and Mitigation Banking Along the Cool Run Watershed at the UD Farm

Environmental Engineering and Economics double major Christophet Youngquist
Advisor: Dr. Paul Imhoff, UD Department of Civil and Environmental Engineering
Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nutrient Treatment of Stormwater Runoff

Environmental Engineering major Katja Burke Environmental Science major Marc Latham
Environmental Science major Chloe Ng
Advisors: Dr. Gerald Kauffman and Mr. Andrew Homsey, co-leaders of the UD WATER project (Watershed Action Team for Ecological Restoration)
Stormwater Modeling in the Fairfield Run Watershed in Newark, Delaware

The current DWRC graduate students include:

Lauren Lechner
Began her Ph.D. program in Environmental Engineering in September 2014
Advisor: Dr. Pei Chiu, UD Department of Civil and Environmental Engineering
Nutrient Removal from Stormwater, Wastewater, and Agricultural Runoff Using Scrap Iron and Biochar

Daniel Sanchez Carretero
Began his Ph.D. program in Environmental Engineering in September 2014 Advisor: Dr. C.P. Huang, UD Department of Civil and Environmental Engineering
Electrochemical Reduction of Dissolved Carbon Dioxide in Water to Hydrocarbons

The DWRC Advisory Panel selected the following 2015-2016 class of 15 water resources:

Environmental Engineering major Samuel Dever
Advisor: Dr. Paul Imhoff, UD Department of Civil and Environmental Engineering
The Effect of Organic Matter on Mineral Weathering

Environmental Engineering major Xiaolun Guo
Advisor: Dr. C.P. Huang, UD Department of Civil and Environmental Engineering
Effect of Temperature on the Kinetics and Thermodynamics of Mineral Solubility

Environmental Engineering major Ryan Hall
Advisor: Dr. Paul Imhoff, UD Department of Civil and Environmental Engineering
Integrating Biochar Amendments in Green Stormwater Management Systems for Enhanced Nitrogen Treatment of Stormwater Runoff

Environmental Science major James Hanes
Advisor: Mr. A. Scott Andres, Delaware Geological Society
Determination of Daily Net Primary Production in Coursey Pond, Delaware

Environmental Engineering major Kelli Kearns
Advisor: Dr. Angelia Seyfferth, UD Department of Plant and Soil Sciences
Biogeochemical Controls on Metal and Nutrient Fluxes in a Protected Estuary in Delaware

Environmental Engineering major Andres Kwart
Advisor: Dr. Anastasia Chirnside, UD Department of Entomology and Wildlife Ecology

Development of a Fungal Biocell Reactor for Treatment of a Food Processing Wastewater

Environmental Science major Alyssa Lutgen

Advisor: Dr. Delphis Levia, UD Department of Geography

The Isotopic Composition of Throughfall in Relation to Drop Size Diameter Distribution

Environmental Science major Jillian Matz

Advisor: Dr. Shreeram Inamdar, UD Department of Plant and Soil Sciences

Pulse of the Watershed: Studying Rapid (Sub-hourly) Changes in Stream Water Quality Using High-frequency, In-situ Sensors

Environmental Engineering major Marcos Miranda

Advisor: Dr. Daniel Cha, UD Department of Civil and Environmental Engineering

Breathable Membrane Enclosures for Fecal Sludge Stabilization: Application in Eco-vapor Toilets

Energy and Environmental Policy, and Economics double major Adam Nesbitt Advisor: Dr. Lawrence Agbemabiese, UD Center for Energy and Environmental Policy Application of the DESEU to Water Resources

Environmental Science major Margaret Orr

Advisor: Dr. Shreeram Inamdar, UD Department of Plant and Soil Sciences

Assessing the Impact of Severe Storm Events on Exported Sediment, Particulate Organic Matter, and Nutrients and Stream Water Quality

Natural Resources Management major Erica Rossetti

Advisor: Dr. Gerald Kauffman, Delaware Water Resources Center

First State National Park: Brandywine-Piedmont Watershed Planning

Environmental Engineering major Samantha Serratore Advisor: Dr. Gerald Kauffman, Delaware Water Resources Center Brandywine-Piedmont Watershed Plan (BPWP)

Plant Science major Nicholas Villari

Advisor: Dr. Amy Shober, UD Department of Plant and Soil Sciences

Understanding the Role of Ditch Sediments in the Transport of Phosphorus in Agricultural Drainage on the Delmarva

Chemistry major Ha Vu

Advisor: Dr. Deb Jaisi, UD Department of Plant and Soil Sciences

Remineralization of Organic Matter and Chesapeake Bay Hypoxia

Award-winning Student Chapter

The DEAWRA Student Chapter at the

University of Delaware has been

selected as the American Water

Resources Association (AWRA)

Outstanding Student Chapter for 2015 .

The official award will be presented to

President Asia Downtin of the DEAWRA

student chapter in November at the

2015 AWRA Annual Conference in Denver, CO. Past winners of the outstanding student chapter include the University of Florida, University of Wisconsin and Oregon State University.



river clean up event in spring 2015.

Narvaez Receives WRADRB Achievement Award

On April 22, 2015 AWRA President-elect Martha Corrozi Narvaez received the prestigious Achievement Award from the Water Resources Association of the Delaware River Basin (WRADRB).

The award was presented at the WRA 33rd Annual Recognition Dinner held at the Downtown Club in Philadelphia, PA. Jerry Kauffman, Director of the DWRC and the University of Delaware Water Resources Agency,

presented the award. The award was given for Narvaez's leadership, contributions and commitment to promoting and advancing practices of conservation and sound management of water and natural resources in the Delaware River Basin.



Left to right, Jerry Kauffman, Dennis Palmer (WRADRB Chairman), Martha Narvaez and Kathy Klein (President, WRADRB) at the WRADRB awards dinner in April 2015.

Jobs in Water Resources

Community Organizer

The TTF Watershed Partnership is seeking to fill a Community Organizer position (half-time) for community outreach efforts for the Philadelphia Water Department's District 4 "Green City Clean Waters" projects. Please see [posting](#) for details. Deadline: September 4.

Partnership for the Delaware Estuary

Watershed Outreach Specialist

The Partnership for the Delaware Estuary (PDE) is looking for a creative, organized and energetic individual to implement educational programs for the protection and enhancement of the resources of the Delaware Estuary. The Specialist will be responsible for duties such as maintaining current and establishing new partnerships with organizations within the Delaware Estuary Watershed to advance the work of PDE. Candidate must demonstrate an ability to work effectively in teams and with diverse public and private constituencies. A Bachelor's degree in an environmental science, outreach or related field is required. A more detailed job description is available on the [website](#). Interested applicants are encouraged to submit a resume by September 10 to: Partnership for the Delaware Estuary, 110 South Poplar Street, Suite 202, Wilmington, DE 19801; or by [email](#).

Coordinator of Grants

The Partnership for the Delaware Estuary, a regional environmental nonprofit organization based in Wilmington, Delaware, seeks a full-time Coordinator of Grants to aid in maintaining and growing PDE's grant funding to support PDE's efforts in the Estuary. This includes researching and prioritizing funding opportunities, working with PDE Directors and staff to develop new proposals, communicating with grant funders, maintaining accurate records and handling grant reporting and administration. A more detailed job description is available on the [website](#). Interested applicants are encouraged to submit a resume, writing sample and names/addresses of three references by September 30 to: Partnership for the Delaware Estuary, Attn: Debbie Heaton, 110 South Poplar Street, Suite 202, Wilmington, DE 19801; or by [email](#).

Delaware Center for Inland Bays

The Delaware Center for the Inland Bays invites applications for its Watershed Coordinator, who will coordinate with partner organizations in the implementation, tracking, and progress reporting for the Inland Bays Comprehensive Conservation and Management Plan, including the Inland Bays Pollution Control Strategy. Position description and application information can be found [here](#).

UD College of Agriculture and Natural Resources

GET ENRICHED! The UD College of Agriculture and Natural Resources internships are listed [here](#).

UD College of Earth, Ocean, and Environment

Visit the [website](#) for news about jobs and internships through the UD College of Earth, Ocean, and Environment.

Delaware Environmental Institute

Visit the DENIN [website](#) for news about fellowships and internships through the Delaware Environmental Institute.

Delaware Nature Society

Job listings with the Delaware Nature Society, celebrating its 50th anniversary, can be found [here](#).

Upcoming Water Conferences and Events

Sep. 8, 2015 -- Protect Your Groundwater Day

The National Ground Water Association (NGWA) reminds that everyone can and should do something to protect groundwater. Find out more [here](#).

Sep. 25, 2015 -- 2nd Annual Water Science and Policy (WSP) Symposium

The public is invited to hear presentations from graduate students in the Interdisciplinary WSP Graduate program from 2:00 – 6:00 PM in UD's Townsend Hall Commons. To learn more about the WSP program, click [here](#). Directions to Townsend Hall can be accessed [here](#).

Sep. 29, 2015 -- Eat for Change (DEAWRA Student Section Fundraiser)

Support the University of Delaware Student Chapter of the American Water Resources Association (AWRA) at Chipotle on 136 Main St. in Newark on Tuesday, September 29th between 5:00pm and 9:00pm. Bring this [flyer](#), show it on your smartphone or tell the cashier you're supporting the cause and 50% of the proceeds will be donated to the student chapter.

Oct. 4, 2015 -- University of Delaware's Coast Day

This annual event, organized by UD's College of Earth, Ocean, and Environment, will feature the Robotic Discovery Laboratory TEACH FLEET, food festivals, and interactive learning to promote marine stewardship and environmental awareness. More information is available [here](#).

Oct. 5–6, 2015 -- 3rd Annual Delaware River Watershed Forum, University of Delaware

Learn about a range of protection and restoration efforts underway, contribute your insights to the development of a watershed-wide vision, tour local sites for a hands-on perspective of different conservation issues and network with your peers at the 3rd Annual Delaware River Watershed Forum sponsored by the Coalition for the Delaware River Watershed and the William Penn Foundation. More information is available [here](#).

Nov. 16–19, 2015 -- 2015 AWRA Annual Water Resources Conference

This year's American Water Resources Association (AWRA) Annual Conference on Water Resources will be held in Denver, CO. Join water resource professionals and students for an engaging week of cutting edge presentations on timely water resource issues, and for dialogue with fellow water resource movers and shakers from across the country and throughout the world. More information is available [here](#).

Water Resources Information and Training

Delaware Sea Grant and local partners have adapted a popular rain garden app for the mid-Atlantic region to help homeowners build their own rain gardens and improve water quality. More information about the app can be found [here](#).

The Delaware Section of the American Water Resources Association meeting information can be found [here](#).

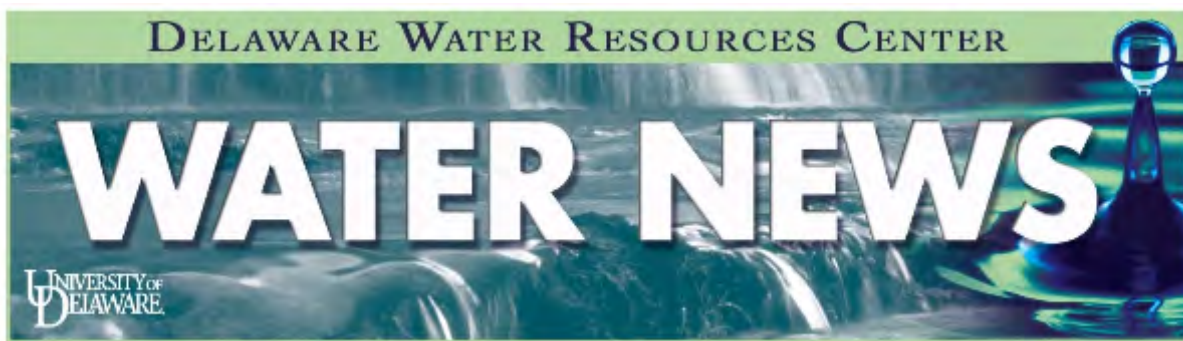
The Delaware Student Section of AWRA activities can be found [here](#).

The Delaware Nutrient Management Commission (as well as other State of Delaware departments) public meeting and workshop information is found [here](#).

Welcome new subscribers! Contributions, comments and questions are always appreciated. Water News serves citizens interested in topics on Delaware water resources and is published by the Delaware Water Resources Center, University of Delaware.

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November 2015

Volume 14

No. 4

Celebrating Our 50th Year!

[View the newsletter online](#)

Director's Remarks



Twenty five has indeed been a watershed year for water resources in the Diamond State. The Delaware Water Resources Center is celebrating the Golden Anniversary of our founding in 1965, just a year after Lyndon Baines Johnson worked with Congress and signed the Water Resources Research Act that formed the 54 National Institutes for Water Resources (NIWR) at land grant universities in the 50 states, D.C. and the three island territories of Guam, Puerto Rico, and U.S. Virgin Islands. The DWRC Advisory Panel has recommended water resources research funding from the USGS that supports 18 undergraduate internships and 3 graduate assistantships to study with faculty and scientists from five colleges at the University of Delaware. In September, the University of Delaware was chosen to host the 3rd Annual Delaware River Forum sponsored by the Coalition for the Delaware River Watershed that highlighted over \$35 million in investments by the William Penn Foundation to 40 nonprofits and universities to protect and restore the

watershed that provides drinking water to 5% of the population of the United States. Accepting the gavel from our NIWR colleague and outgoing President Dr. John Tracy (Director of the University of Idaho Water Resources Research Center), the University of Delaware Water Resources Center's Martha Narvaez was inducted on November 18, 2015 as the 50th President of the American Water Resources Association at the AWRA annual conference in Denver, Colorado. Completing the flow of good news, past president and geography doctoral candidate Asia Dowtin and current president and Water Science and Policy graduate student Sandra Petrakis accepted

the award in Denver on November 15, 2015 as the University of Delaware was recognized as 2015 outstanding AWRA student chapter at the annual AWRA conference in Denver, Colorado. National champs! I wonder what the next ten years will bring for us here at the DWRC. Diamonds anyone?

Three 2015-16 UD WATER Interns Named

The UD WATER Project (Watershed Action Team for Ecological Restoration) was formed in 2008 as a collaborative initiative with the long-term goal of merging and facilitating university-wide efforts to minimize the environmental impacts of stormwater runoff from the University of Delaware campus.

UD WATER brings together a consortium of faculty, staff, and students from various disciplines across campus to work collaboratively to implement creative and innovative storm water management techniques. The ultimate goal for this team is to reduce the quantity and increase the quality of storm runoff from campus properties, which will ultimately benefit our local waterways and is consistent with the mission of EPA regulations requiring the University and City of Newark to have a National Pollutant Discharge Elimination System (NPDES) permit.

A new cohort of three UD undergraduate interns recently attended their first UD WATER meetings; they are now in the process of selecting their topic area(s). The 2015-16 UD WATER interns are (pictured left to right):

junior Environmental Engineering major Norma Brasure - she is very interested to serve in the Peace Corps after gaining skills in water resources and improvements of water and sanitation facilities; junior Environmental Science major Clare Sevcik - she has spent summers monitoring streams in Virginia and Maine and recently studied the effect of sea level rise on brownfields in Wilmington, Delaware; and senior Environmental Science major Gemma Antoniewicz - she feels that increasing awareness of the effects that everyday actions can have on the environment, especially through environmental education, is an important step towards reducing society's impact on the natural environment. Their project progress will soon be available on a new and improved UD WATER website.



Spotlight on 2015-16 DWRC Undergraduate Internships

Ask UD's Department of Geography DWRC intern Margaret Orr about the weather and she may very well tell you about her ongoing research project, "Assessing the Impact of Severe Storm Events on Exported Sediment, Particulate Organic Matter, and Nutrients and Stream Water Quality." Margaret, pictured in a lighter work moment, shares: "This summer, I worked with Masters' candidate Doug Rowland in Dr. Shreeram Inamdar's lab in UD's Department of Plant and Soil Sciences. We worked in the

laboratory as well as in the field at the Fair Hill Natural Resource Management Area in nearby Cecil County, Maryland. Doug's research focuses on soil and sediment, and as one of UD's new Meteorology and Climatology majors, I wanted to find a way to link Doug's research to my interests in weather. My project focuses on connecting weather data to sediment loading and sediment properties during storm events. Severe weather is projected to not only become more frequent but also more intense as climate change occurs, and I wanted to investigate the effects that storm intensification could have on



Margaret Orr conducting field work at Fair Hill Natural Resources Management Area.

sediment loading and streams. One of my tasks was to help collect data following storms by filtering sediment out of water samples collected by two automated water samplers that are set up in Fair Hill. Some of the sediment that remained on the filter was put into capsules and sent for isotope analysis. I have been assessing weather data from the Delaware Environmental Observing System (DEOS) Automated Surface Observation System station in Fair Hill as well as some sediment data collected from storms to find correlations between weather parameters and sediment parameters, such as lag time between peak rainfall and peak sedimentation. Although the work is far from finished, I plan to devote most of my time over UD's winter session to completing my project."

3rd Annual Delaware River Watershed Forum

The 3rd Annual Delaware River Watershed Forum was held at the University of Delaware on October 5-6, 2015 following the first two symposium at the Academy of Natural Sciences at Drexel University in 2013 and in Bethlehem near Lehigh University in 2014. Over 300 participants from throughout the Delaware River Watershed in Delaware, New Jersey, New York, and Pennsylvania learned



Photo caption: Green infrastructure bike tour through the University of Delaware campus and City of Newark, DE, led by DWRC Director, Jerry Kauffman. Photo taken at the top of the Newark Reservoir.

about a range of protection and restoration efforts underway, contributed insights to the development of a watershed-wide vision, toured local sites for a hands-on perspective of different conservation issues, and networked with peers at this event sponsored by the Coalition for the

Delaware River Watershed and the William Penn Foundation. The Delaware River Watershed Initiative is part of a \$35 million investment by the William Penn Foundation to protect and restore the 13,000 square mile that provides drinking water in four states to over 15 million people (5% of the nation's population) and the first (New York City) and 7th largest metropolitan economies in the United States.

Prominent speakers from Delaware who discussed the economic and ecological value of the Delaware River Watershed to the First State included Governor Jack Markell, Congressman John Carney, DNREC Secretary David Small, and National Wildlife Federation President Collin O'Mara. DWRC Director Jerry Kauffman spoke about "Water Use in the Delaware River Basin" during the opening plenary session.

Read the forum overview [here](#) and visit the Coalition's Facebook page [here](#).

National Champs! University of Delaware student chapter recognized as 2015 Outstanding Student Chapter of the American Water Resources Association.

On November 15, 2015, the University of Delaware was honored with the award for 2015 Outstanding Student Chapter by the American Water Resources Association (AWRA) at the annual conference in Denver, Colorado.

Each year the AWRA bestows this award upon the student chapter that best fulfills its mission through:

1. the advancement of water resources-based research, planning, development, management, and education,
2. the creation of common meeting times and spaces in which interdisciplinary scholars, practitioners, and citizens concerned with the provision and safety of water resources can convene, and
3. the collection, organization, and dispersion of pertinent and/or innovative ideas and information regarding the supply, management, and preservation of water resources.



Photo: From left to right: Amanda Doremus, Samantha Brucker, Matt Luddington, Laura Askin, Kelsey Moxey, Kristen Molfetta, Sandra Petrakis, Asia Dowtin and John Tracy (AWRA President)

Over the course of the academic year, the UD Student Chapter of the DE-AWRA has led many initiatives, including the annual Water Resources Career Night, Winter in the Watershed Holiday Party and Networking Event, and monthly discussion-based meetings.

Through generous contributions from the AWRA, the Delaware section of the AWRA (DE-AWRA), and UD Water Resources Agency, eight UD students were able to attend the 2015 annual conference and awards reception. Outgoing president and UD geography doctoral candidate Asia Dowtin (College of Earth, Ocean, and Environment) accepted the award from AWRA President John C. Tracy, Director of the University of Idaho Water Resources Research Institute. Also representing the UD student AWRA chapter were graduate students Amanda Doremus (Geography), Samantha Brucker (Urban and Regional Planning), Matthew Luddington (Water Science and Policy), Laura Askin (Public Administration), Kelsey Moxey (Water Science

and Policy), Kristen Molfetta (Water Science and Policy), DE-AWRA student chapter president Sandra Petrakis (Water Science and Policy).

Past recipients of the Outstanding Student Chapter award include Pennsylvania State University, University of Florida, University of Washington, University of Wisconsin, and Oregon State University.

The University of Delaware Student AWRA Chapter was founded in 2005 and is advised by Martha Narvaez and Gerald Kauffman from the University of Delaware Water Resources Center.

UD's Martha Narvaez inaugurated as the 50th President of the American Water Resources Association

On November 18, 2015, the University of Delaware's Martha Narvaez was inducted as the 50th President of the American Water Resources Association at the AWRA annual conference in Denver, Colorado. Martha accepted the gavel from outgoing President John C. Tracy who is the Director of the University of Idaho Water Resources Research Institute in Boise, Idaho. Martha will serve her term during 2016 and follows predecessors from

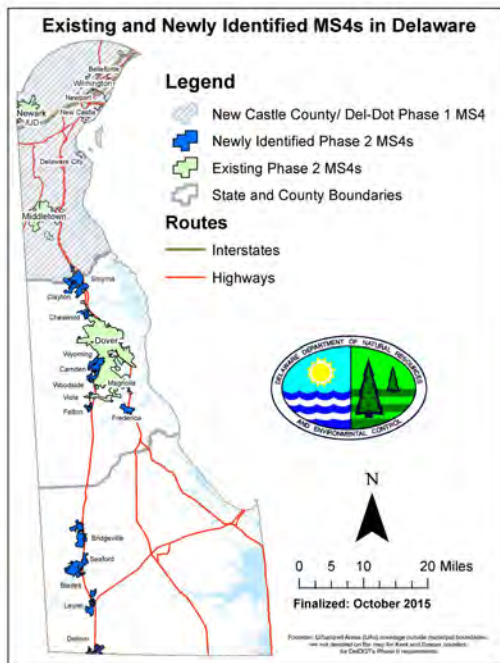
institutions of higher learning such as Texas A&M, Pennsylvania State University, University of Wisconsin, and University of Illinois. Martha Narvaez, Policy Scientist with the University of Delaware Water Resources Center in the Institute for Public Administration and School of Public Policy and Administration, has also served as founding President of the Delaware state chapter of the AWRA and co-founder of the University of Delaware student section of the AWRA. Established in 1964 the AWRA has over 2,100 members, has sponsored 120 symposia over the last 50 years in the U.S. and abroad with over

30,000 attendees, and publishes the Journal of the American Water Resources Association (JAWRA) with an impact factor ranking in the upper third of peer publications. The University of Delaware Water Resources Center is one of the 54 National Institutes for Water Resources (NIWR) supported by the U.S. Department of Interior at land grant universities in the 50 states, District of Columbia, and the island territories of Guam, Puerto Rico, and U.S. Virgin Islands.



Photo: Martha Narvaez accepting the gavel from current AWRA President, John Tracy.

MS4 Permit Changes in Delaware: Will You Be Ready?



The Delaware Department of Natural Resources and Environmental Control (DNREC) has released its new draft MS4 general permit. Based on expansion of Urban Areas as of the 2010 decennial census, several additional communities in Delaware are now required to submit a permit application to discharge their storm water into the waters of Delaware.

On November 5th at Heritage Shores Golf Club in Bridgeville, Delaware the Delaware Section of the American Water Resources Association (DEAWRA), in partnership with DNREC, held a fall symposium, "MS4 Permit Changes in Delaware: Will You Be Ready?" The MS4 fall symposium discussed the upcoming MS4 (Municipal Separate Storm Sewer Systems) permit changes in Delaware. The event was sponsored by RK&K, Pennoni, KCI Technologies,

Duffield Associates, Sussex Conservation District and New Castle Conservation District.

Secretary Small and the Surface Water Discharge Section, along with the EPA, MS4 regulated communities and many other organizations were present to discuss the new proposed regulations and answer questions that regulated entities, water resource professionals, and the public may have. Karl Graybill from the City of Lancaster, PA, the keynote speaker, discussed green infrastructure projects in the City of Lancaster. In closing Bryan Ashby provided remarks on what's on the horizon for MS4 communities. The day concluded with a DEAWRA social hour.

See the website of the [Delaware section of the American Water Resources Association](#) (DEAWRA) for more information.

Map credit: DNREC

Jobs in Water Resources

Delaware Center for the Inland Bays
Entry-level Environmental Scientist

The Delaware Center for the Inland Bays is inviting applicants for an entry-level Environmental Scientist who will assist with scientific research, monitoring, and habitat restoration projects in the Inland Bays watershed. The Center—a National Estuary Program—is a private, nonprofit organization located at the Indian River Inlet, in Delaware Seashore State Park near Rehoboth Beach, Delaware. This full-time position, with benefits, will be hired for a one-year term, which may be extended as funding allows. The position will remain open until an appropriate candidate is selected; for best consideration, apply by December 18, 2015A more detailed description can be found [here](#)

Delaware Nature Society
Director of Sites and Visitor Experience

The Delaware Nature Society (DNS) is looking for a leadership team member who is an active participant in making strategic decisions affecting the organization and provides leadership and direction for all DNS sites as places where visitors connect with nature through unique, relevant, authentic hands-on experiences. Support implementation of strategic vision and goals at each site, and work with site managers to assure a high-quality visitor experience at all sites that meet the needs of the community and targeted audience. Assure adoption of best practices and facilitate strong internal communication, networking and team collaboration among all sites and staff in mission-related and support departments. A more detailed job description is available on the [website](#)

UD College of Agriculture and Natural Resources

GET ENRICHED! The UD College of Agriculture and Natural Resources internships are listed [here](#).

UD College of Earth, Ocean, and Environment

Visit the [website](#) for news about jobs and internships through the UD College of Earth, Ocean, and Environment.

Delaware Environmental Institute

Visit the DENIN [website](#) for news about fellowships and internships through the Delaware Environmental Institute.

Delaware Nature Society

Additional job listings with the Delaware Nature Society, celebrating its 50th anniversary, can be found [here](#).

Upcoming Water Conferences and Events

Winter in the Watershed Holiday Party

Save the date for the third annual Winter in the Watershed Happy Hour on December 4, 2015, 6-8 pm at Klondike Kate's on Main Street in Newark, Delaware. This event is co-hosted by the University of Delaware, Water Resources Agency, the Delaware Section of the American Water Resources Association (DEAWRA) and the DEAWRA Student section.

International Conference on Environmental Science and Technology 2016

The International Conference on Environmental Science and Technology 2016 sponsored by the American Academy of Sciences will be held on June 6-10, 2016 in Houston, Texas, USA. The conference will provide a multidisciplinary platform for environmental scientists, engineers, management professionals and government regulators to discuss the latest developments in environmental research and applications. Please visit the conference [website](#) for more information or send email to env-conference@AASci.org.

Water Resources Information and Training

From WaterSense, a USEPA Partnership: Get Schooled on Water Savings - and Pass It On

WaterSense has completed a series of fun and informative videos featuring Flo, the WaterSense spokesperson, which show how you can save water year-round. From switching showerheads to

checking for leaks, WaterSense has the viral videos that can inspire your friends and followers. View some of them [here](#)

Free, downloadable e-books are available from the International Water Association's IWA Water Wiki [website](#). Vol. 1 titles include "[Constructed Wetlands for Pollution Control](#)" and "[Integrated River Basin Governance](#)" can be found in Vol. 2.

Delaware Sea Grant and local partners have adapted a popular rain garden app for the mid-Atlantic region to help homeowners build their own rain gardens and improve water quality. More information about the app can be found [here](#).

The Delaware Section of the American Water Resources Association events information can be found [here](#).

The Delaware Student Section of AWRA activities can be found [here](#).

The DENIN events calendar is found [here](#).

The Delaware Nutrient Management Commission (as well as other State of Delaware departments) public meeting and workshop information is found [here](#).

Welcome new subscribers! Contributions, comments and questions are always appreciated. Water News serves citizens interested in topics on Delaware water resources and is published by the Delaware Water Resources Center, University of Delaware.

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Basic Information:**Delaware Water Resources Center Electronic Newsletter WATER E-NEWS**

Title:	"WATER E-NEWS"
Issues during FY15:	Volume 14 Issues 1, 2
Description:	Brief online "highlights" newsletter published periodically by the Delaware Water Resources Center
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Gerald J. Kauffman, Director; Maria Pautler, Editor

WATER E-NEWS is received electronically by over 300 recipients in water-related academic, government, public and private agency, agriculture and industry positions in Delaware and the surrounding area. The current issue and back issues dating to its August 2002 inception may be accessed via the DWRC website at: <http://ag.udel.edu/dwrc/newsletters.html>.

Featured in each issue of WATER E-NEWS are:

- I. News items about the DWRC, including undergraduate internships and graduate fellowships
- II. Jobs in Water Resources
- III. Upcoming Water Conferences / Events
- IV. Water Resources Information / Training

WATER E-NEWS

March 2015
Volume 14 Issue 1

Delaware Water Resources Center (DWRC) <http://ag.udel.edu/dwrc/>
Our 50th Year!
UD Water Resources Agency (WRA) <http://www.ipa.udel.edu/wra>

In this month's issue, online at <http://ag.udel.edu/dwrc/> :

- I. **DWRC NEWS**: Intern Mentors / Projects Needed; Poster Session
- II. **JOBS IN WATER RESOURCES**: 2015-16 DWRC Internships – **Mar. 27 deadline**
- III. **UPCOMING WATER EVENTS**: Mar. 7 Environmental Summit – **Mar. 4 deadline**
- IV. **WATER RESOURCES INFORMATION / TRAINING**: USGS Water Use Circular



I. DWRC NEWS

Mentors / Projects Needed: 2015-16 DWRC Undergraduate Internship Program

- *Current project proposals*:
http://ag.udel.edu/dwrc/jobs/2015-16/DWRC_Undergrad_Internship_Proposals-2015_and_Older.pdf
- *Application information*: <http://ag.udel.edu/dwrc/internships.html>

Students having a 3.0 GPA or better enrolled at any Delaware institute of higher learning (except those graduating in Spring 2015) may **apply through Mar. 27, 2015** for DWRC's undergraduate internships and earn up to \$3500 at the rate of \$10 per hour worked. DWRC's research and education opportunities are especially attractive to undergraduates seeking mentored experiences leading to publication and possibly a degree with distinction or senior thesis. All interns must have the active support of a mentor who matches intern earnings 2:1, usually through a commitment of time to the project. Advisors may mentor up to two students concurrently.

If you would like to mentor a deserving DWRC intern and/or propose a project of up to 350 hours to be completed by Feb. 29, 2016, contact Maria Pautler at 302-831-0847 or mpautler@udel.edu.

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Internship project topics are diverse. Here is one project that would be best suited to a communications, marketing, or journalism major:

Community Engagement Internship - Chesapeake Watershed Implementation Plan  
(Read more about this project on the next page.)

Improvements in water quality require planning and cooperation. The goal of this project is to inform communities about the Chesapeake Watershed Implementation Plan and establish community-based efforts to reduce pollutant loads that reach and impair the Chesapeake Bay waters.

The Community Engagement Intern will work directly with the DNREC Community Ombudsman to support the development of the Chesapeake Bay Watershed Implementation Plan's Diversity Action Team. The position will be housed at the DNREC Site Investigation and Remediation Section, 391 Lukens Drive, New Castle, Delaware, 19720. The student will be expected to work from this location during the summer months. The incumbent will improve communications and outreach efforts to multicultural communities by identifying: local organizations and contacts, baseline knowledge of water pollution, and opportunities to inform and educate by utilizing local media sources used by the audience we seek to engage.

It is our goal to expand the diversity of the workforce and communities involved in Chesapeake restoration and conservation activities based on race, income levels, faith, gender, sexual orientation and disability. The intern will: develop direct questionnaires and telephone surveys; conduct the survey of the watershed; analyze survey; evaluate communications alternatives and set priorities; and develop and publish a final project report.

Additional duties include: compiling contact lists of multi-cultural organizations and contacts within the Chesapeake Bay Watershed; developing surveys to identify community-based organizations and the baseline knowledge of watershed residents; Identifying the demographic characteristics of the targeted communities; inventorying and cataloging local media including radio, television, social media, newsletters, periodicals; creating or updating ACCESS databases; and preparing mailings and print production.

Interested? Contact James Brunswick (DNREC), [James.Brunswick@state.de.us](mailto:James.Brunswick@state.de.us) or Joseph Farrell (UD), [jfarrell@udel.edu](mailto:jfarrell@udel.edu).

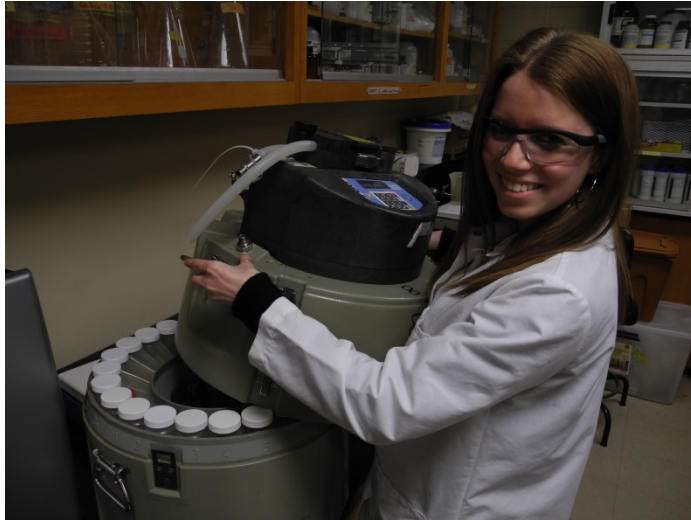


**Friday, April 17, 2015: Free** DWRC 2014-15 Undergraduate Internships research project Poster Session, part of larger session sponsored by UD Undergraduate Research Scholars Program. 2:00 – 4:30 PM., UD Trabant University Center Multipurpose Rooms A, B & C, Newark, DE. (<http://maps.rdms.udel.edu/map/index.php?id=NW22>)

Visit <http://www.udel.edu/water/> to learn about the activities of **UD WATER (Watershed Action Team for Ecological Restoration)**.

Learn about other internship project possibilities by visiting the links in Section II below.

*Now celebrating our 50<sup>th</sup> year, new developments within the DWRC will be reported in future issues. A current intern success story is found on the next page.*



Shining the spotlight on a finishing 2014-15 *DWRC* intern, UD environmental science major Amanda Doremus shares her experience with exploring water quality from paired bioretention basins on UD's south campus. Doremus, whose work was co-sponsored by UD's Department of Plant and Soil Sciences and directed by Dr. Carmine Balascio, writes, "The *DWRC* internship research project I have been working on studies bioretention stormwater control measures and

their ability to treat stormwater in compliance with regulations. The purpose of this specific research is to compare the results of water treatment using a standard Delaware Department of Natural Resources and Environmental Control (DNREC) media verses an advanced media within the bioretention system. Over the past summer, I collected stormwater samples of major rain events from three water samplers. One sampler collected water after it had passed through the standard DNREC media; another, after it passed through the advanced media. The third sampler was located at the head of the system to capture untreated stormwater. Before storm events, I programmed each of the samplers, and then afterwards I collected the samples and brought them back to the lab. Each week I ran phosphorus and nitrogen tests in the water lab; several other tests were done as well. Since it is now winter and there are no major storms to prepare for, I have been working on maintenance of the samplers and compiling data that have been recorded thus far. I have enjoyed working on this part of the research and am excited to see the conclusions of the project."

## II. JOBS IN WATER RESOURCES

**2015-16 Delaware Water Resources Center undergraduate internships.** See I above.

**GET ENRICHED! - UD College of Agriculture and Natural Resources** internships are listed at <http://canr.udel.edu/current-undergraduate-students/canr-resources/internships/>

Visit <http://www.ceoe.udel.edu/academics/jobs-internships> for news about jobs and internships through the **UD College of Earth, Ocean, and Environment**.

Visit <http://denin.udel.edu/fellowships-internships> for news about fellowships and internships through the **Delaware Environmental Institute**.

Job listings with the Delaware Nature Society, also celebrating its 50<sup>th</sup> anniversary, are found here:

[http://www.delawarenaturesociety.org/DNS/About\\_Us/Employment/DNS/Employment.aspx](http://www.delawarenaturesociety.org/DNS/About_Us/Employment/DNS/Employment.aspx).

### III. UPCOMING WATER CONFERENCES / EVENTS

#### **Mar. 6-8, 2015: Lights, Camera, EARTH!**

Co-sponsored by the Delaware Environmental Institute, UD's environmental film festival, free and open to the public, will be held in Mitchell Hall on UD's main campus. Learn more at the festival website: <http://www.denin.udel.edu/lce-film-festival>.

#### **Saturday, Mar. 7, 2015: Delaware Environmental Summit**

This annual summit will be held at Wesley College in Dover, DE, starting at 9:30 AM. The plenary session will include several short presentations about emerging issues in the First State and there will be four breakout sessions. **Register by Wed., Mar. 4** by visiting <http://delaware.sierraclub.org/2015-environmental-summit>.

#### **Mar. 24 OR 26, 2015: Home Gardener Workshop - I Hate My Lawn (but I want to learn to love it!)**

Grow the lawn you want with fewer chemicals and less water! This comprehensive course will help you recognize lawn problems and learn how to cure them. Topics include soil conditioning, choosing a grass type, sod versus seed, fertilizing, mowing, pest management and more. Held at the New Castle County Cooperative Extension Office from 6:30 – 8:30 PM. Fee charged. E-mail [cjmurphy@udel.edu](mailto:cjmurphy@udel.edu) to register.

#### **Mar. 26-28, 2015: Annual Conference of the Mid-Atlantic Chapter of the Society of Ecological Restoration: A Celebration of Mid-Atlantic Restoration**

Hosted by the University of Delaware at the Clayton Hall conference center, this educational conference also includes a skills-based workshop and field trips. Find the many details by visiting <http://chapter.ser.org/midatlantic/annual-conference/> and <http://www.eventbrite.com/e/society-for-ecological-restoration-mid-atlantic-chapters-10th-annual-conference-tickets-15013521848>

#### **Apr. 11, 2015: Spring Community Clean-up Day**

9:00 – 11:00 AM. Meet at the City of Newark Municipal Building. T-shirts will be given to the first 200 volunteers. Visit <http://www.cityofnewarkde.us>.

**Apr. 18, 2015: Kids' Greenfest**, presented by the Newark Center for Creative Learning. Deemed **"Sustainable Fun for Everyone!"**, this **free** event runs from 10:00 AM – 3:00 PM. Visit <http://www.ncclschool.com/>.

**Apr. 25, 2015: UD College of Agriculture and Natural Resources 40th annual Ag Day**, themed **"Farm to Table"** and UD Botanic Gardens Spring Plant Sale. Rain or shine, 10:00 AM – 4:00 PM. Visit <http://ag.udel.edu/agday>.

The **Delaware Section of the American Water Resources Association** meeting information is found at <http://www.deawra.org/>.

#### IV. WATER RESOURCES INFORMATION / TRAINING

The Nov. 4, 2014 USGS Circular "*Estimated Use of Water in the United States in 2010*" is available online. The report, fact sheet, and data are found here: <http://pubs.usgs.gov/circ/1405/> and the news release is found here: [http://www.usgs.gov/newsroom/article.asp?ID=4048&from=rss\\_home](http://www.usgs.gov/newsroom/article.asp?ID=4048&from=rss_home).

**National Groundwater Awareness Week is March 8-14, 2015.** For details visit <http://www.ngwa.org/Events-Education/awareness/Pages/default.aspx>.

**Every Drop Counts - Fix a Leak Week is March 16-22, 2015.** For details visit [http://www.epa.gov/watersense/our\\_water/winter2015.html](http://www.epa.gov/watersense/our_water/winter2015.html).

Learn more about the **Mar. 22, 2015 World Water Day** by visiting <http://www.unwater.org/worldwaterday/>.

For the calendar of 2015 spring semester **UD Plant and Soil Sciences** seminars visit <http://canr.udel.edu/plsc/plsc-seminar-calendar/>.

The **DENIN** events calendar is found here: <http://denin.udel.edu/events>.

**Sierra Club Student Coalition** offers Summer Programs (SPROG) for Environmental Leadership Training. Visit <http://www.ssc.org/>.



Welcome new subscribers! Contributions, comments and questions are always appreciated. Water E-News serves citizens interested in topics on Delaware water resources and is published by the Delaware Water Resources Center, University of Delaware. Our address: 113 Townsend Hall, Newark, DE 19716-2103. Phone: 302-831-0847; fax: 302-831-0605; Web: <http://ag.udel.edu/dwrc/>. Dr. Gerald Kauffman, Director, email [jerryk@udel.edu](mailto:jerryk@udel.edu); Maria Pautler, Program Coordinator, email [mpautler@udel.edu](mailto:mpautler@udel.edu). To unsubscribe, email [mpautler@udel.edu](mailto:mpautler@udel.edu) with "Unsubscribe Water E-News" in the subject line.

# WATER E-NEWS

April 2015  
Volume 14 Issue 2

Delaware Water Resources Center (DWRC) <http://ag.udel.edu/dwrc/>  
*Our 50<sup>th</sup> Year!*

UD Water Resources Agency (WRA) <http://www.ipa.udel.edu/wra>

In this month's issue, online at <http://ag.udel.edu/dwrc/> :

- I. **DWRC NEWS**: 2014-15 DWRC Internship Poster Session; AWRA Scholarship
- II. **JOBS IN WATER RESOURCES**: 2015-16 DWRC Internships Announced Soon
- III. **UPCOMING WATER EVENTS**: 45<sup>th</sup> Anniversary of Earth Day, Dam Removal
- IV. **WATER RESOURCES INFORMATION / TRAINING**: USGS Report on Water Quality



## I. DWRC NEWS

### 2014-15 DWRC Undergraduate Internship Program Poster Session

**Friday, Apr. 17, 2015: Free and open to all interested individuals**

DWRC 2014-15 Undergraduate Internships research project Poster Session, part of larger session sponsored by UD Undergraduate Research Scholars Program. 2:00–4:30 PM, UD Trabant University Center Multipurpose Rooms A, B & C, Newark, DE.  
(<http://maps.rdms.udel.edu/map/index.php?id=NW22>)

Learn more: <http://urp.udel.edu/content/poster-session-2015>



**THE 2015-16 RICHARD A. HERBERT MEMORIAL SCHOLARSHIP APPLICATION PERIOD IS NOW OPEN: For AWRA undergraduate and graduate student members**

Submittal Information: <http://awra.org/about/scholarships/index.html>

Application packets for 2015-16 should be submitted to [info@awra.org](mailto:info@awra.org). Applications must be submitted electronically as one document and limited to 5mb in size to ensure delivery. **Applications are due Apr. 22, 2015.** Please call 540-687-8390 or email [info@awra.org](mailto:info@awra.org) with any questions concerning the submittal process.

## II. JOBS IN WATER RESOURCES

### **2015-16 Delaware Water Resources Center undergraduate internships**

The newest internship projects will be announced in a future issue of Water News.

**GET ENRICHED! - UD College of Agriculture and Natural Resources** internships are listed at <http://canr.udel.edu/current-undergraduate-students/canr-resources/internships/>

Visit <http://www.ceoe.udel.edu/academics/jobs-internships> for news about jobs and internships through the **UD College of Earth, Ocean, and Environment**.

Visit <http://denin.udel.edu/fellowships-internships> for news about fellowships and internships through the **Delaware Environmental Institute**.

Job listings with the Delaware Nature Society, celebrating its 50<sup>th</sup> anniversary, are found here:

[http://www.delawarenaturesociety.org/DNS/About\\_Us/Employment/DNS/Employment.aspx](http://www.delawarenaturesociety.org/DNS/About_Us/Employment/DNS/Employment.aspx).

## III. UPCOMING WATER CONFERENCES / EVENTS

### **Apr. 11, 2015: Spring Community Clean-up Day**

9:00 – 11:00 AM. Meet at the City of Newark Municipal Building. T-shirts will be given to the first 200 volunteers. Visit <http://www.cityofnewarkde.us>.

### **Apr. 18, 2015: Brandywine Creek Stream Clean-up**

9:00 AM – 12:00 PM. Join The Nature Conservancy, Delaware Parks, and the National Park Service in exploring New Castle County's Piedmont region while helping [keep streams clean](#) during the first Brandywine StreamStewards Cleanup! This event is a partner to the Christina River Watershed Clean-up. To find meet-up locations visit <http://www.nature.org/ourinitiatives/regions/northamerica/unitedstates/delaware/events/>.

### **Apr. 21, 2015: History of Daniel Byrnes at the Hale-Byrnes House and site visit to historic dam removal project on the White Clay Creek. Register by Apr. 17.**

Please join us for this unique opportunity to visit the Hale-Byrnes House and a site visit to a historic dam removal project on the White Clay Creek. The special program is being held from 2:00-4:00 PM and is free to all DEAWRA members; the non-member fee is \$10. To register, contact Rick Mickowski at [Rick.Mickowski@state.de.us](mailto:Rick.Mickowski@state.de.us) or 302-832-3100 ext. 113. Learn more: <http://deawra.wildapricot.org/Resources/Documents/hale-byrnes%20and%20dam%20removal%20tour.pdf>

### **Apr. 22, 2015: 45<sup>th</sup> Anniversary of Earth Day!**

Celebrate with a choice from UD's Earth Month schedule: <http://www.udel.edu/earthmonth/>

**Apr. 22, 2015: 33<sup>rd</sup> Annual Recognition Dinner of the Water Resources Association of the Delaware River Basin. RSVP by Apr. 17.**

Visit [http://wradrb.org/calendar\\_dtl.php?id=18&d=2015-04-22](http://wradrb.org/calendar_dtl.php?id=18&d=2015-04-22).

The UD WRA's Martha Narvaez is being honored with this year's Achievement Award!

**Apr. 25, 2015: UD College of Agriculture and Natural Resources 40th annual Ag Day**, themed **"Farm to Table"** and **UD Botanic Gardens Spring Plant Sale**. Rain or shine, 10:00 AM – 4:00 PM. Visit <http://ag.udel.edu/agday>.

**May 2, 2015: 7<sup>th</sup> Annual White Clay Creek Fest**

12:00 – 4:00 PM. Carpenter Recreation Area, White Clay Creek State Park. Learn more: <http://www.whiteclay.org>.

**May 15-17, 2015: Venture Outdoors Fest**

This event is designed to get Delawareans engaged with the outdoors. You must be at least 18 years old to attend. Learn more: <http://destateparks.com/vfest/>.

The **Delaware Section of the American Water Resources Association** meeting information is found at <http://www.deawra.org/>.

#### IV. WATER RESOURCES INFORMATION / TRAINING

From Bruce Lindsay, USGS, [blindsey@usgs.gov](mailto:blindsey@usgs.gov), 717-730-6964:

A new USGS [report](#) describes the occurrence of, trends in, and factors controlling concentrations of contaminants in the Northern Atlantic Coastal Plain surficial aquifer system. Titled "The Quality of Our Nation's Waters: Water Quality in Principal Aquifers of the United States, 1991–2010", the report highlights how geology, hydrology, geochemistry, and chemical use affect the concentrations of contaminants from both geologic and manmade sources.

<http://pubs.usgs.gov/circ/1360/>.

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From WaterSense, a USEPA Partnership: *Listen to Your Mother (Nature) This Earth Day*

For Earth Day this year, celebrate the water planet by using water outdoors the way Mother Nature intended and making every drop count this spring planting season. From selecting regionally appropriate blooms to knowing when and how much to water, you can be a water-saving force of nature this Earth Day with a lush and low-maintenance landscape. For these and other tips, visit

http://www.epa.gov/watersense/our_water/spring2015.html#one.

For the calendar of 2015 spring semester **UD Plant and Soil Sciences** seminars visit <http://canr.udel.edu/plsc/plsc-seminar-calendar/>.

The **DENIN** events calendar is found here: <http://denin.udel.edu/events>.

Sierra Club Student Coalition offers Summer Programs (SPROG) for Environmental Leadership Training. Visit <http://www.ssc.org/>.



Welcome new subscribers! Contributions, comments and questions are always appreciated. Water E-News serves citizens interested in topics on Delaware water resources and is published by the Delaware Water Resources Center, University of Delaware. Our address: 113 Townsend Hall, Newark, DE 19716-2103. Phone: 302-831-0847; fax: 302-831-0605; Web: <http://aq.udel.edu/dwrc/>. Dr. Gerald Kauffman, Director, email jerryk@udel.edu; Maria Pautler, Program Coordinator, email mpautler@udel.edu. To unsubscribe, email mpautler@udel.edu with "Unsubscribe Water E-News" in the subject line.

Basic Information: Delaware Water Resources Center Website

Title:	Website: http://ag.udel.edu/dwrc
Start Date:	Third edition; since February 2009
End Date:	Ongoing
Description:	Comprehensive site serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Gerald Kauffman, Director; Maria Pautler, Administrator

The website contains:

- **Delaware Water Resources Center (DWRC) and Director's News:** Latest updates on DWRC activities and information on the DWRC's mission, history, and role in the National Institute of Water Resources (NIWR).
- **Delaware Water Concerns:** Summary of the major areas of concern related to Delaware's ground and surface waters, with links to key organizations and agencies responsible for water quality and quantity.
- **Projects and Publications:** Descriptions of DWRC's undergraduate internship and graduate fellows programs, annual conference proceedings, and project publications dating back to 1993. Abstracts from the undergraduate internship projects are prevalent to educate current undergraduates and faculty about the types of research that can be done under this program.
- **Advisory Panel:** Purpose, contact information and e-mail links for the DWRC's Advisory Panel.
- **Request for Proposals and Application Forms:** For undergraduate interns, graduate fellowships and other funding opportunities available through the DWRC.
- **Internships and Job Opportunities:** Information on undergraduate and graduate internships from a wide variety of local, regional, and national sources along with current job opportunities in water resource areas.
- **Water Faculty and Courses:** List of researchers at Delaware universities with an interest in water resources research; link from many of the researchers' names to their professional websites to learn about water-related courses currently offered by the researchers
- **Water Resources Contacts:** Links to local, regional, and national water resource agencies and organizations categorized as government, academia, non-profit, and US Water Resource Centers.
- **Calendar:** Upcoming local, regional, and national water resources events sponsored by the DWRC and other agencies, such as conferences, seminars, meetings, and training opportunities.
- **Newsletters:** Access to DWRC newsletters dating back to 1993.
- **Annual and 5-year Reports:** DWRC annual and 5-year reports, dating to 1993.
- **KIDS' Zone:** Water resources activities and information for kids and teachers.

Basic Information: Delaware Water Resources Center E-group / Courses Link

Title:	Delaware Water Resources Center / Water Resources Agency E-group, originating from the online listing of Delaware water teachers and researchers found on the DWRC website: http://ag.udel.edu/dwrc/faculty_researchers.html
Start Date:	Since December 2001
End Date:	Ongoing
Description:	E-group and link to university water resources courses taught, serving Delaware water resources community
Lead Institute:	Delaware Water Resources Center
Principal Investigators:	Gerald Kauffman, Director; Maria Pautler, Administrator

The online listing of approximately 60 researchers at the University of Delaware, Delaware State University, and Wesley College found on the Delaware Water Resources Center website at http://ag.udel.edu/dwrc/faculty_researchers.html forms the foundation for a broader e-group list maintained by the DWRC reaching additional academic, public, private, and government water community contacts, who are notified via an e-mail newsletter of events and job postings of interest in water resources.

The website also provides a link from many of the researchers' names to their professional websites to learn about water-related courses currently offered by the researchers.

Basic Information:**Delaware Water Resources Center Annual Advisory Panel Meeting / Intern Project Celebration of Undergraduate Engaged Scholarship**

Title:	DWRC Advisory Panel Meeting / University of Delaware 2016 Celebration of Engaged Undergraduate Scholarship
Date:	February 29, 2016 and April 29, 2016, respectively
Description:	The annual meeting of the DWRC Advisory Panel was held in February 2016. It featured presentations by the two DWRC-funded graduate students and a few of the undergraduate interns. All of the undergraduate interns presented their 2015-2016 DWRC-funded projects at the April event.
Lead Institute:	University of Delaware Undergraduate Research Program
Principal Investigators:	Iain Crawford, Director, UD Undergraduate Research Program (icrawf@udel.edu); Gerald J. Kauffman, Director, DWRC (jerryk@udel.edu)

UD WATER

Basic Information

Title:	UD WATER
Project Number:	2015DE276B
Start Date:	3/1/2015
End Date:	2/29/2016
Funding Source:	104B
Congressional District:	DE-001
Research Category:	Not Applicable
Focus Category:	Education, Surface Water, Non Point Pollution
Descriptors:	None
Principal Investigators:	Gerald Joseph Kauffman, Maria Pautler

Publication

1. Antoniewicz, G., N. Brasure, C. Sevcik, and G. Kauffman, 2016, The DWRC UD WATER Program: Silver Brook Watershed Plan, 2016, Delaware Water Resources Center, University of Delaware, Newark, Delaware, 15 pages.

The DWRC UD WATER Program: Silver Brook Watershed Plan

Gemma Antoniewicz
Norma Brasure
Clare Sevcik
University of Delaware
Newark, Del.

Abstract

The University of Delaware Watershed Action Team for Ecological Restoration (UD WATER), with support from the Delaware Water Resource Center (DWRC) and Water Resources Agency (WRA), seeks to develop management techniques to minimize the environmental impacts of stormwater runoff from campus. The purpose of the project this year was to create a watershed plan for the Silver Brook that can be utilized to evaluate flooding in the Silver Brook watershed within the University of Delaware's campus. The methods used for this project started with delineating the storm watershed for the Silver Brook. Then, the runoff within the watershed was analyzed by modeling its drainage system through use of the Environmental Protection Agency's Storm Water Management Model (EPA SWMM). UD WATER proposed a plan to decrease the flooding on campus and surrounding City of Newark. Flooding was assessed by modeling a stormwater park at the Rodney DORMS, replacing pipes, and daylighting Silver Brook on STAR campus. From the data collected in SWMM modeling, the proposed plan with all three methods reduced flooding by almost 90% from the current conditions. The model created can be passed along to DNREC and other groups for them to use to implement these plans and further eliminate flooding.

Introduction

The University of Delaware acquired what is currently the Science, Technology, and Advanced Research (STAR) campus in 2009. Sections of the campus are heavily dominated by unused impervious surface, and some soil has been contaminated due to the former presence of a Chrysler plant. These contaminated areas are now undergoing a brownfield remediation. Development plans for the unused impervious area have been partially completed with the addition of a California-based company, Bloom Energy, which manufactures fuel cells, and UD's Health Sciences Complex. As for the rest of the area, the University is in the process of planning for future development. Any development plans for this area will impact the Silver Brook watershed and stormshed, as a large portion of the STAR campus is a part of the Silver Brook watershed. The Silver Brook watershed covers an area of approximately 633.75 acres in Newark, Delaware with 46% impervious cover. The area includes a large portion of the STAR campus, UD's retired West Campus, multiple residential areas, Phillip's Park, and a segment of Newark's Elkton Road. All runoff that enters the stormwater drainage system within this area eventually makes its way into the Silver Brook and eventually into the Christina River.

The UD Watershed Action Team for Ecological Restoration (UD WATER) Project dedicated the 2016 Spring semester to assessing the stormwater runoff entering the Silver Brook by evaluating the City of Newark's stormwater piping system. In particular, the UD WATER Project modeled how precipitation impacts the land area within the Silver Brook storm watershed as well as the piping system's ability to handle various storm events within the Silver Brook watershed. The UD WATER Project's team of undergraduate interns spent the semester analyzing the flooding in the area and formulating solutions to lessen its effects.

The first objective of this project was to delineate the storm watershed boundaries using GIS data for the topography and flow directions of the surrounding area. Second, the runoff within the delineated boundary was assessed using the Environmental Protection Agency's Storm Water Management Model 5.1 (SWMM). Third, proposing management plans to alleviate the flooding in the area by incorporating current proposals from the City of Newark and UD were analyzed using SWMM to assess the reduction in flood volume.

Background

- Why did we choose Silver Brook watershed
 - Rodney and Dickinson Dorms being converted to a Newark "Stormwater" Park
 - STAR Campus has headwaters at location of dorms
 - Silver Brook runs underground (piped)
- Upper Christina River watershed
 - Flows through three states (PA to MD to DE)
 - On UD's campus
 - 1 of 6 trout streams in DE
 - Drinking Water Intake Suez Delaware, Smalleys Pond on Christiana River
 - Is overseen by the nonprofit Christina Conservancy

The Silver Brook Creek is a tributary of the Christina River, one of four drinking water intake streams in Delaware. The Silver Brook flows first into Christina Creek which then discharges into the Christina River, of which many segments do not meet water quality standards for dissolved oxygen, nutrients, and bacteria. The Christiana River is one of only 6 trout streams in Delaware and is overseen by the Christina Conservancy. The Silver Brook watershed currently consists of 43% urban and 57% pervious material. Table 1 describes the hydrologic soil groups found in the Silver Brook watershed. The total watershed area consists of 736 square acres.

Table 1. Hydrologic Soil Groups of the Silver Brook watershed

Hydrologic Soil Group— Summary by Map Unit — New Castle County, Delaware (DE003)				
Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
ErB	Elsinboro-Delanco-Urban land complex, 0 to 8 percent slopes	B	205.4	27.9%
GhB	Glenn-Wheaton-Urban land complex, 0 to 8 percent slopes	B	33.2	4.5%
Hw	Hatboro-Codorus complex, 0 to 3 percent slopes, frequently flooded	B/D	7.1	1.0%
MtB	Mattapex silt loam, 2 to 5 percent slopes	C	10.7	1.5%
MuB	Mattapex-Urban land complex, 0 to 5 percent slopes	C	88.0	12.0%
OtA	Othello silt loam, 0 to 2 percent slopes	C/D	9.3	1.3%
Up	Urban land		311.3	42.3%
UzC	Udorthents, 0 to 10 percent slopes	A	29.9	4.1%
VoB	Urban land-Othello complex, 0 to 5 percent slopes		31.5	4.3%
WoB	Woodstown loam, 2 to 5 percent slopes	C	9.6	1.3%
Totals for Area of Interest			736.1	100.0%

The site in need of restoration was the location of a Chrysler Plant, active from 1951 to 2008. When the Chrysler plant was built, the Silver Brook was buried underground in an 84” culvert under coal slag. In 2009, the University of Delaware purchased the site and began redeveloping it as the STAR Campus. The portion of STAR that was formerly the Chrysler plant is now owned by 1743 Holdings LLC, a wholly-owned subsidiary of the University of Delaware. The Silver Brook drains areas of the University’s main campus, the STAR Campus, residential neighborhoods, and over 100 acres of industrial impervious surfaces from the former Chrysler plant site. Figure 1 shows the Silver Brook Watershed and underground Silver Brook culvert.

Methods

First, we delineated the watershed boundary for the Silver Brook based on flow directions, topography and stormwater drainage system from GIS. Then, we used SWMM modeling for current conditions to put in Newark stormwater drainage system with elevations, pipe dimensions and manning’s coefficient for concrete pipes ($n=0.013$). The watershed then needed to be divided into subcatchments based on flow directions and piping system. We inputted precipitation data for 2, 10, and 100 year storms, and for Hurricane Sandy & a recent storm that occurred on February 24th, 2016. The storm data was collected from DEOS website, and put into SWMM in hourly increments vs. rainfall rate (in/hr) for 24 hours. Once we ran the model, data was collected for amount of flooding. The SWMM model could then be modified for the future conditions. The future model we created added a stormwater park to Rodney dorns by replacing piping by Rodney dorns with a storage node, and entered tabular data for storage nodes which included depth of proposed pond vs. area covered. Then, we daylighted the Silver Brook

by removing the pipe that contained that Silver Brook underground and added an open-trapezoidal conduit with a new Manning coefficient ($n = 0.03$) to act as a stream. We changed pipes that were too small to fit surrounding pipes in order to reduce flooding in those areas. We then ran the simulations again, and compared the resulting data to that of the original model.

Results

All storm simulations were run in one-hour increments across a 24-hour time period. The 2-Year Storm Event produced a total runoff of 56.1 million gallons across our 15 subcatchments. Twelve nodes were reported as flooded over the course of the storm, with a total flood volume of 9.38 million gallons. The 10-Year Storm Event had a total of 80.0 million gallons of total runoff across the subcatchments and a reported 16.1 million gallons for the total flood volume from 13 flooded nodes. The 100-year storm had, as anticipated, the largest amount of total runoff and total volume of node flooding, with 141.9 million gallons and 32.4 million gallons respectively. Additionally, we simulated two storms of different magnitudes, Hurricane Sandy (2012) and the 24 February 2016 rain event. Hurricane Sandy produced 67.2 million gallons of total runoff and 9.74 million gallons of total flood volume. The February storm had 15.2 million gallons of total runoff and a total flood volume of 1.64 million gallons (See Figure 2).

There have been two proposed scenarios to reduce flooding during a 10-year storm event. The first scenario being daylighting the portion of Silver Brook that is currently buried under the STAR campus, and the second being the installation of a stormwater park where the Rodney Dormitory complex is currently located. With these two modifications, the amount of total runoff and total flood volume were 57.9 million gallons and 5.90 million gallons respectively. By daylighting the stream, we assumed removal of the current impervious cover down to 25% and assumed stream size would be roughly equivalent to the size of the current pipe. There are four acres available for the construction of a stormwater park. With a six-foot deep pond that fills depending on the amount of runoff during a storm event, the maximum amount of water during a 10-year storm event is well within the holding capacity.

These modifications reduced the total flood volume by 63.5%, to 5.90 million gallons, from the current conditions, but flooding still occurs in large amounts in select areas, namely around Trabant. By enlarging select pipes within the stormshed, the total flood volume was reduced further to 1.72 million gallons, 89.3% of the current conditions (See Figures 3 and 4).

Discussion

With the given current conditions, nodal flooding occurs with all rainfall events. The locations of flooded nodes is consistent with locations that are commonly observed and reported as flooded. For the 10-year storm, a majority of the flooded nodes (54%) were located around Trabant Student Center. This flooding is primarily due to a lack of adequate pipe sizes. The current stormwater piping system cannot handle the sheer

amount of water. Thus, the water must pool above ground, which causes the flooding. As depicted in Figure 3, the number of flooded nodes was reduced significantly when pipes were strategically enlarged (Figures 7 and 8).

While the proposed stormwater park did reduce flooding, it did not fix the largest problem areas. The proposed placement of the stormwater park collects water from the system above the train tracks, which act as a dam, allowing no water to cross without pipes. The locations where flooding is an issue is below the proposed stormwater park location. The addition of the stormwater park and the daylighting of the Silver Brook reduce flooding, but not at a statistically significant amount ($p = 0.13$) at an alpha level of 0.1. The addition of enlarged pipes, however, cause a statistically significant reduction in flooding from the current conditions ($p = 0.06$). Figure 8 shows the differences between the flood volume among the three scenarios.

Based on these findings, we strongly recommend a reassessment of current pipe dimensions within the stormshed and the strategic enlargement of pipes around problem areas. The input of a stormwater park will reduce flooding, but it will be most effective in addition to pipe enlargements. A stormwater park with a depth of six to eight feet and an area of four acres is recommended to prevent overflow during a 10-year storm event. A daylighted stream is also recommended for the alleviation of flooding and reduction of runoff across the STAR campus. Daylighting the stream will work best with the current impervious cover being reduced from an average of 94% to 25%, a dramatic reduction from the current conditions.

Figures



Figure 1. Silver Brook watershed and culvert

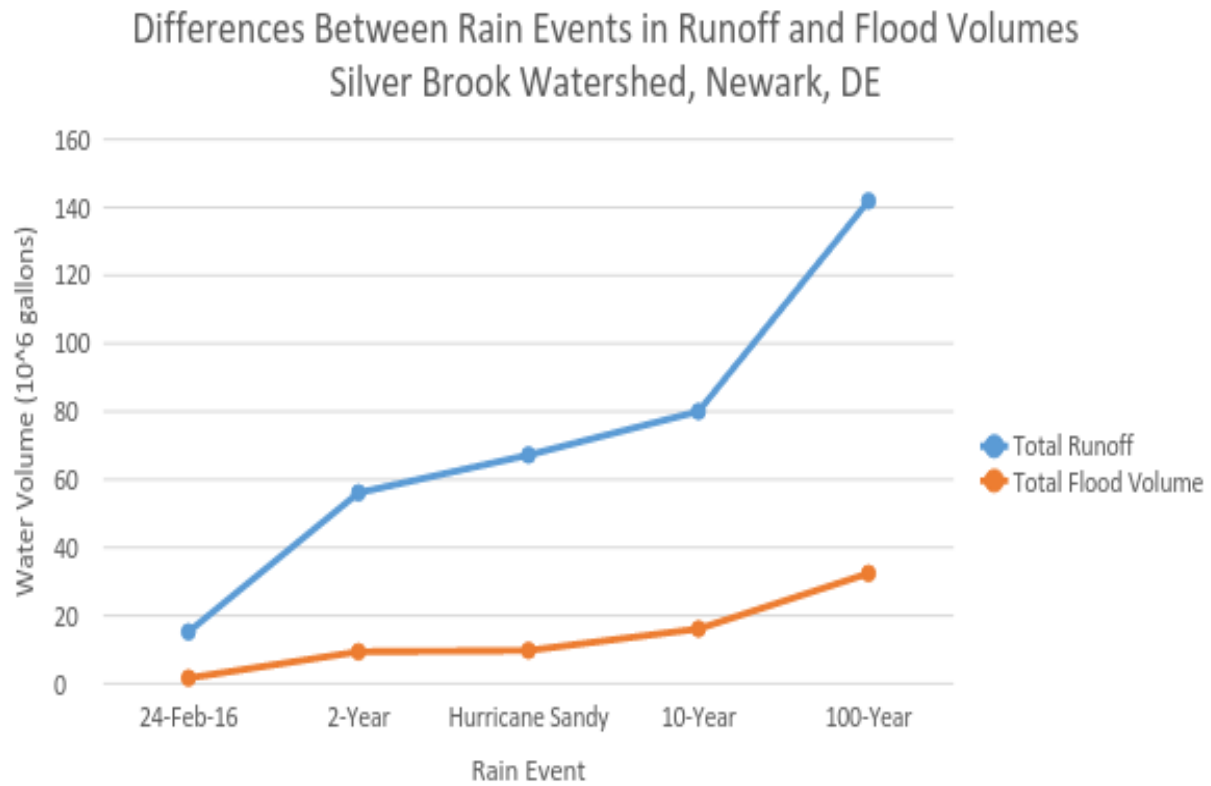


Figure 2. Total volume of runoff and flood volume from the 15 subcatchments within the Silver Brook storm watershed for various storm events.

Total Volume of Node Flooding During a 10-Year Storm Event Silver Brook Watershed, Newark, DE

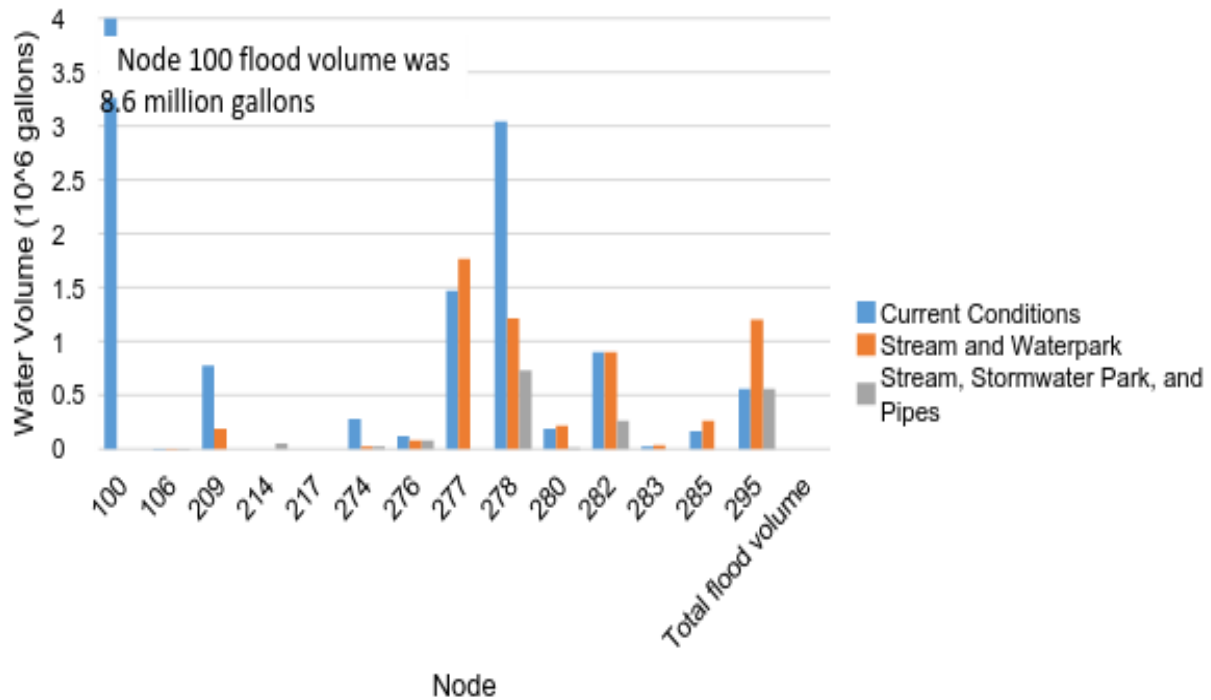


Figure 3. Flood volume for the SWMM model in the Silver Brook storm watershed.

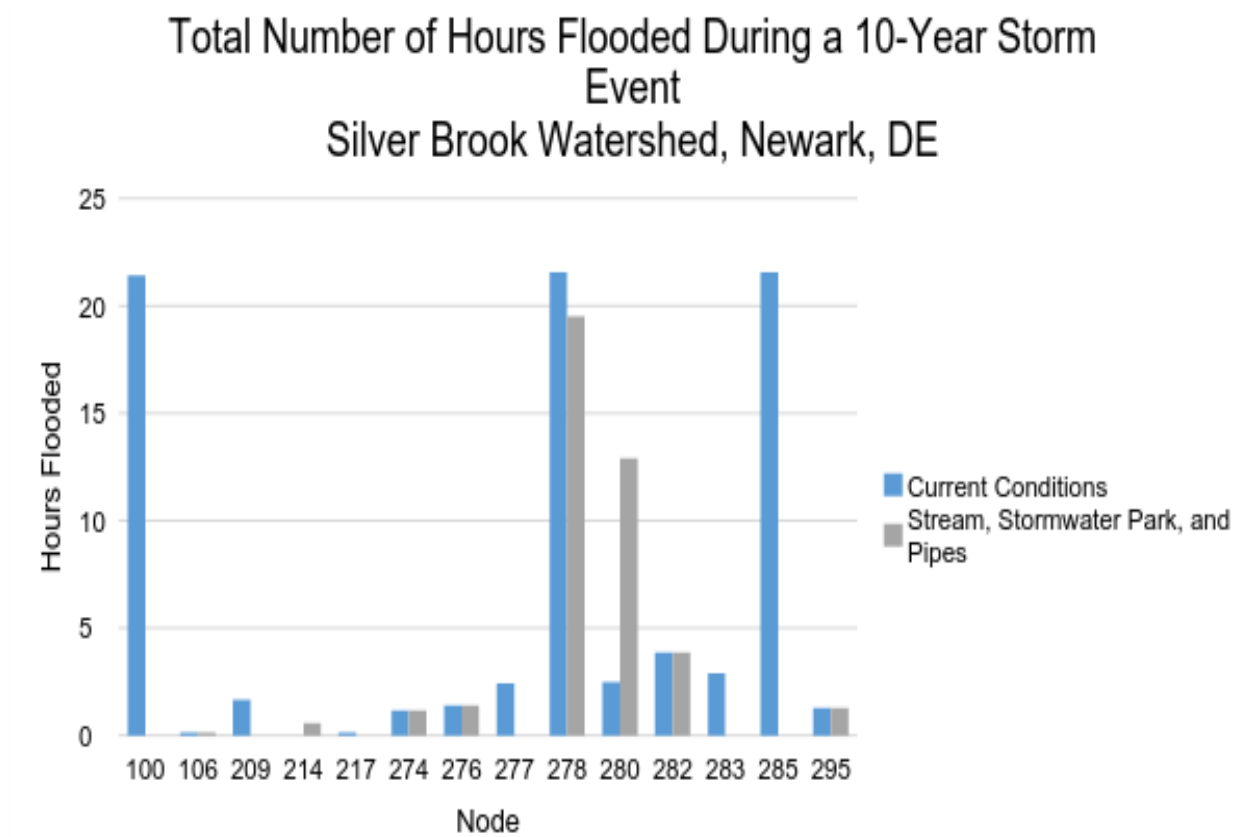


Figure 4. Hours of flooding during a 10-year storm event in the Silver Brook storm watershed.

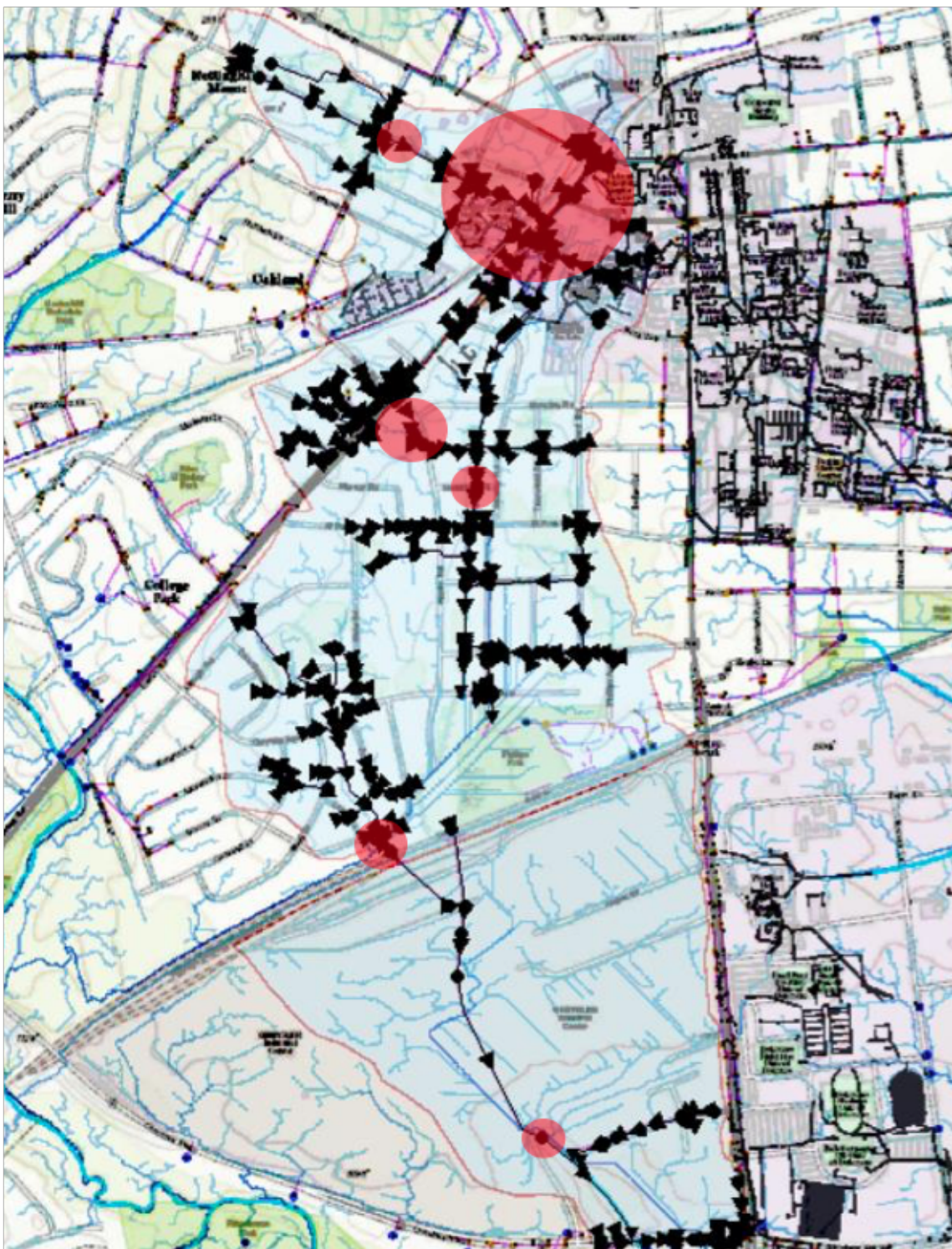


Figure 5. The Silver Brook storm watershed with flooding during a 10-year storm with the size of the red highlight corresponding to the number of nodes that are flooded.

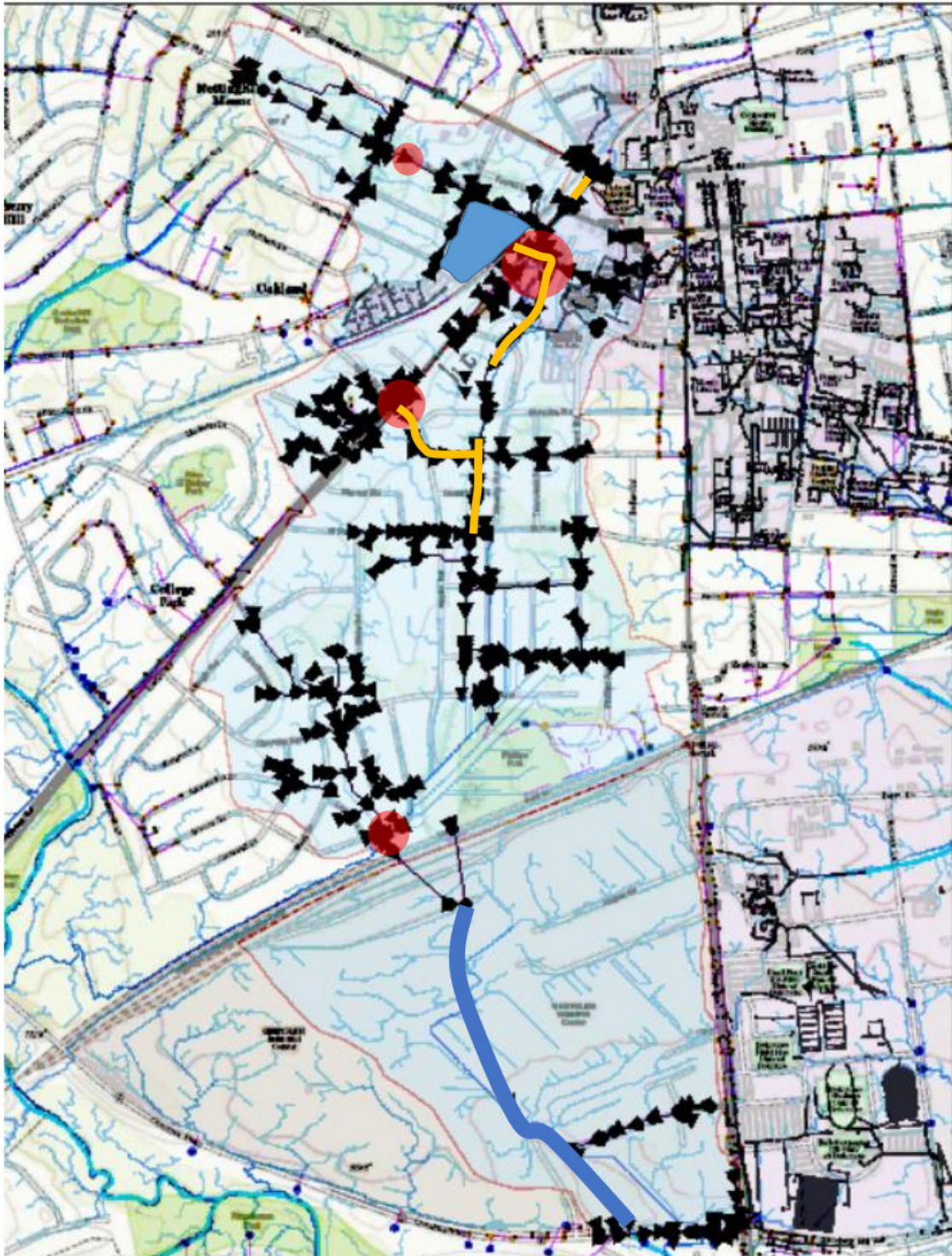


Figure 6. The Silver Brook storm watershed with a proposed stormwater park (blue), enlarged pipes (orange), and daylighted stream (green) on the STAR campus. Flooding areas for a 10-year storm event are highlighted in red.

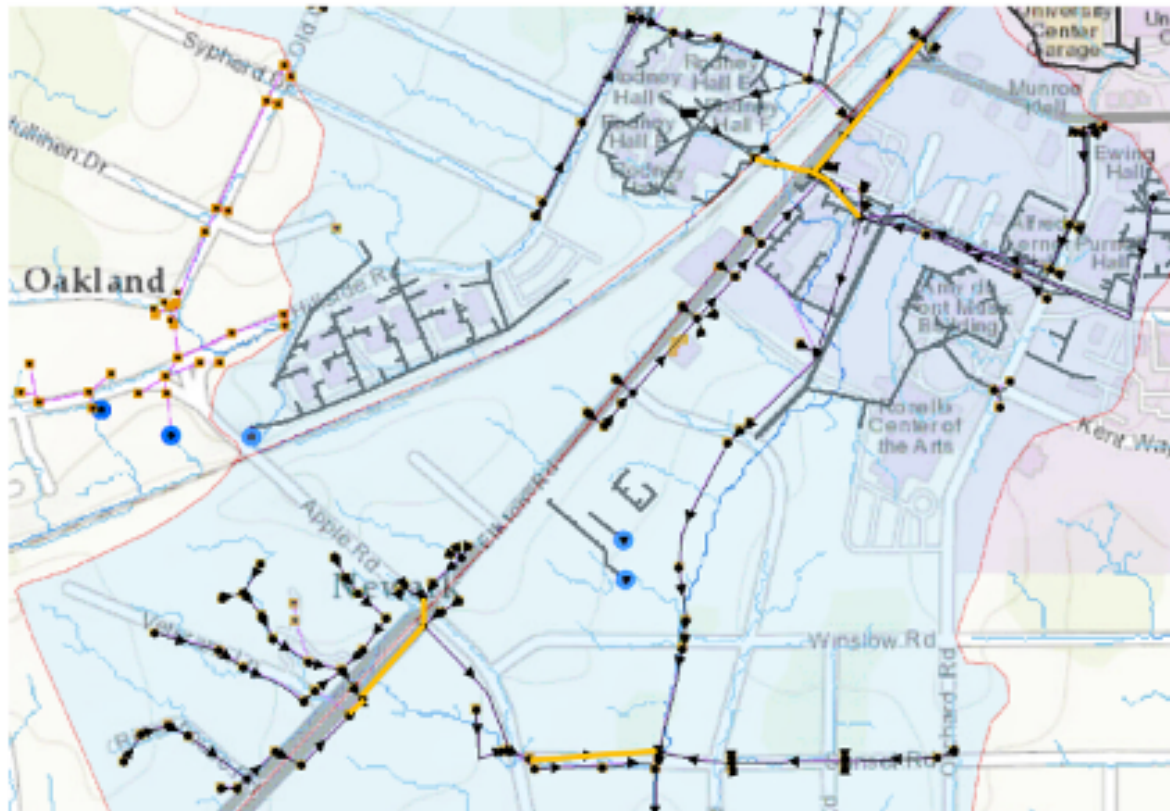


Figure 7. Location of enlarged pipes within the Silver Brook storm watershed, depicted by yellow lines.

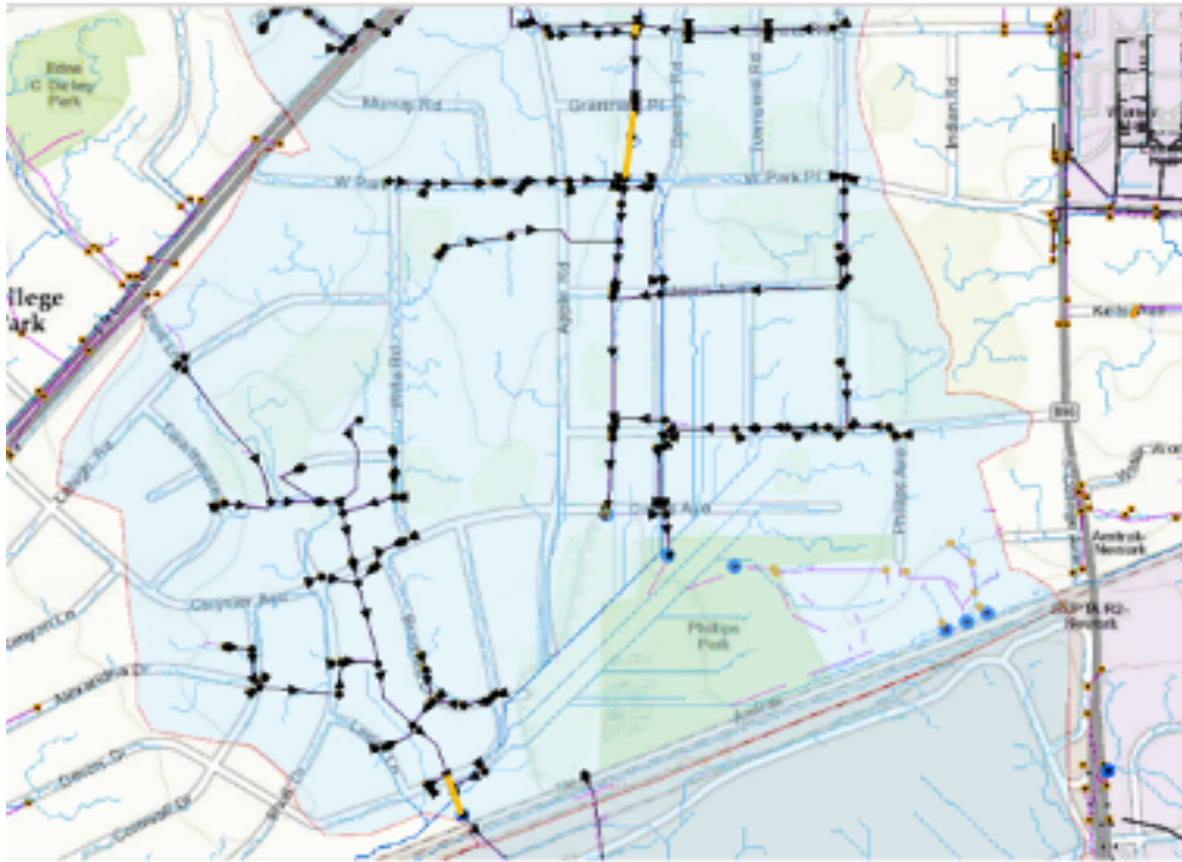


Figure 8. Location of enlarged pipes within the Silver Brook storm watershed, depicted by yellow lines.

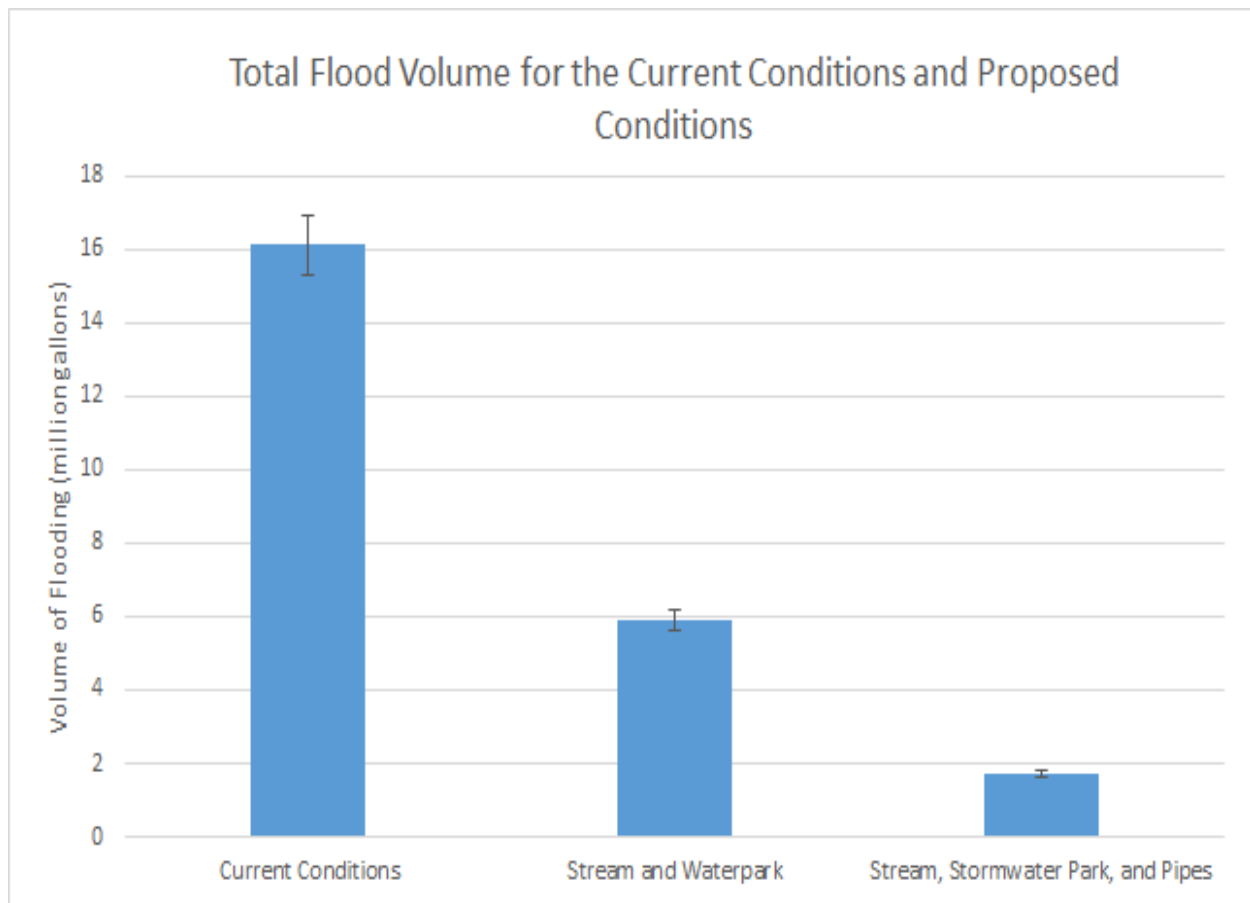


Figure 9. A comparison between the resulting total flood volumes during a 10-year storm event in the Silver Brook watershed. The three conditions are depicted.

USGS Summer Intern Program

None.

Student Support					
Category	Section 104 Base Grant	Section 104 NCGP Award	NIWR-USGS Internship	Supplemental Awards	Total
Undergraduate	19	0	0	0	19
Masters	1	0	0	0	1
Ph.D.	1	0	0	0	1
Post-Doc.	0	0	0	0	0
Total	21	0	0	0	21

Notable Awards and Achievements

WRADRB Achievement Award

On April 22, 2015 AWRA President-elect and DWRC Policy Scientist Martha Narvaez received the prestigious Achievement Award from the Water Resources Association of the Delaware River Basin (WRADRB). The award was presented at the WRA 33rd Annual Recognition Dinner held at the Downtown Club in Philadelphia. DWRC Director Dr. Gerald Kauffman presented the award for Narvaez's leadership, contributions and commitment to promoting and advancing practices of conservation and sound management of water resources in the Delaware River Basin.

DWRC's Martha Narvaez Inducted as 51st President of AWRA

Accepting the gavel from NIWR colleague and outgoing President Dr. John Tracy (Director of the University of Idaho Water Resources Research Center), the DWRC's Martha Narvaez was inducted on November 18, 2015 as the 51st President of the American Water Resources Association at the annual conference in Denver, Colorado. Martha is serving her term during 2016 and follows predecessors from institutions of higher learning such as Texas A&M, Penn State, University of Wisconsin, and University of Illinois. Martha served as founding President of the Delaware state chapter of the AWRA and co-founder of the University of Delaware student section of the AWRA. Established in 1964 the AWRA has over 2,100 members, sponsored 120 symposia over the last 50 years with over 30,000 attendees, and publishes the *Journal of the American Water Resources Association* with an impact factor in the upper third of rankings.

UD Named 2015 Outstanding AWRA Student Chapter

Completing the flow of good news, past president and geography Ph.D. candidate Asia Dowtin and current president and Water Science and Policy graduate student Sandra Petrakis accepted the award in Denver on November 15, 2015 as the University of Delaware was recognized as 2015 outstanding AWRA student chapter at the annual conference in Denver, Colorado. Past winners of the outstanding student chapter include the University of Florida, University of Wisconsin and Oregon State University. The UD Student AWRA Chapter was founded in 2005 and is advised by Martha Narvaez and Gerald Kauffman from the DWRC.

Task Force Appointment

During 2015-2016, DWRC Director Gerald Kauffman has been appointed by Delaware Senate Resolution 30 to serve on the Delaware Clean Water and Flood Control Task Force that is charged with developing a sustainable funding mechanism for water resources projects in the First State.

Publications from Prior Years

1. 2010DE171B ("Microbiome of the Eastern Oyster, *Crassostrea virginica*") - Dissertations - Sakowski, E.G., 2015, The Microbiome of the Eastern Oyster, *Crassostrea virginica* in Health and Disease, Ph.D. Dissertation, Department of Biological Sciences, College of Arts and Sciences, University of Delaware, Newark, Delaware, 243 pages.